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ARTICLES

PRINCIPAL LARVAL AND ADULT HABITATS OF *ANOPHELES FARAUTI* LAV. IN THE BRITISH SOLOMON ISLANDS

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INTRODUCTION

The "sphere of influence" (1) of the *punctulatus* group of mosquitoes covers an area of the East Indian Archipelago east of the Celebes and Roma, all of the Moluccas, New Guinea, the Bismarck Archipelago, the British Solomon Islands, the New Hebrides and Northern Australia. Except for a single record from the Banggai Islands off the east coast of the Celebes, there is no invasion of members of this group of mosquitoes west of Wallace's line.

The taxonomy of the six species of anophelines known to date from the Solomon Islands is covered in the recent studies of Rozeboom and Knight (2) Belkin, Knight and Rozeboom (3), Belkin and Schlosser (4), Owen (5), Knight and Farner (6), and Belkin (7). Of the six species, some of which are reported from Bougainville, Guadalcanal and the New Georgia group of islands, only *Anopheles farauti* Lav. is the most widespread and common inhabitant of all the major islands in this group (see Fig. 1); wherever encountered, it was demonstrated to be the primary vector of malaria and filariasis.

* ACKNOWLEDGMENTS: Acknowledgment is made to Commander J. S. Cowan, MC, USN, Commanding Officer, Naval Medical Field Research Laboratory, for the valuable suggestions afforded the author in the preparation of this report. The entomologic assistance of Dr. Alan Stone of the U. S. Department of Agriculture, is warmly appreciated.

The opinions or conclusions contained in this report are those of the author. They are not to be construed as necessarily reflecting the views or endorsement of the Navy Department or the Naval Service at large.

Entomologic surveys revealed a remarkable adaptability of the larvae of *farauti* to develop in environments distinctive to specific oceanic islands in the Australian region. Studies conducted during the dry and wet seasons indicated that within the narrow epidemiologic constellation of the British Solomon Islands ecologic problems existed which were peculiar to each of the six major and seventeen minor islands surveyed at this time. As more field experience was gained in the progressive occupation of malarious islands, entomologists quickly realized that *Anopheles farauti* Lav. gave little warning for the role to be played in its future extent in new areas on many bases occupied by Allied troops. The infiltration of this species into clearings and catchments resulting from the physical alteration of primary jungle terrain was rapid and insidious. As the establishment of northern bases of the Solomon Islands was undertaken, the pooled cooperative energies of engineers and malariologists were spent in the construction of main roads of travel, the preparation of adequate storage surfaces and the elimination of primary foci of breeding to prevent the needless dispersal of this nomad species.

LARVAL HABITATS

The ecologic "niches" enjoyed by larvae of *Anopheles farauti* Lav. are, in general, somewhat specific throughout this area. These breeding sites emphasize the repeated maxim that *anophelines exhibit a selective environmental individuality, and that representative members of the genus tend to utilize characteristic types of water*

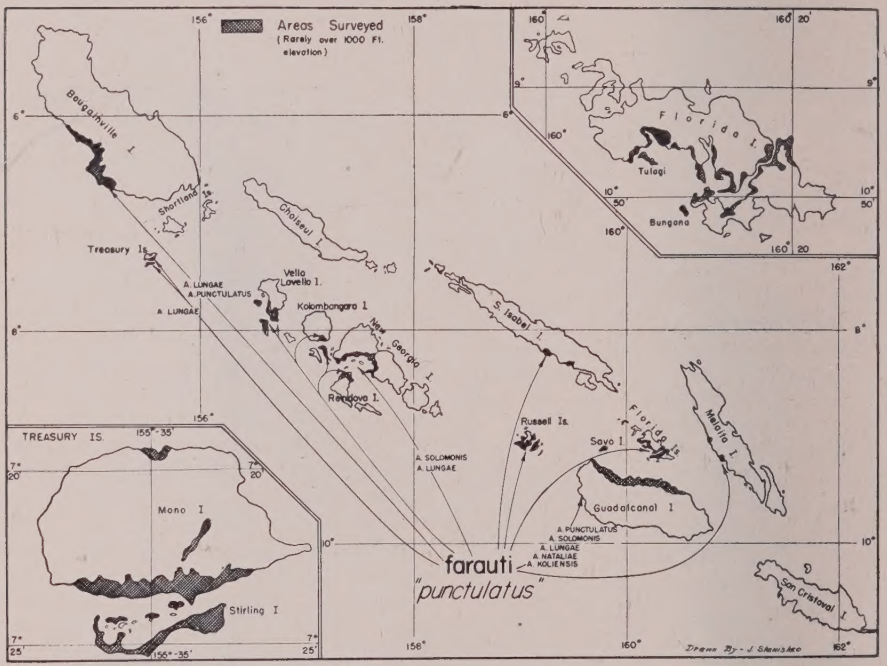

FIGURE 1—Map showing distribution of Anophelines and extent of areas surveyed in the British Solomon Islands.

surfaces compatible for continued development and species survival.

In two years' study of *farauti* in the New Hebrides and the Solomon Islands (8,9), certain dry season habitats were reliable sources for collecting aquatic forms. Sunlit river and stream margins with protective, emergent vegetation yielded the highest larval counts. (Fig. 2) Heavily shaded streams and swiftly running, open bodies of water rarely produced larvae of *farauti* while fresh water swamps, animal wallows, and hoof prints in close proximity to native huts or villages were of localized importance. Undisturbed canebreak swamps were infrequently invaded and in many instances, until seasonal and complete biologic studies could be made, it was difficult to explain the continued absence of aquatic forms of *Anopheles* in certain swamps and ponds located within flight range of adult anopheline populations.

Records obtained from collections extending through the wet seasons were indicative of a passive transportation of aquatic forms from their confined "zones of survival" to an unselective extensive area previously known to be devoid of breeding. Thus, with prolonged periods of rainfall, specimens could be collected in varied catchments, illustrating the adaptability of *farauti* to a wide variety of water surfaces in spite of its well known selective, dry season habitats. The most productive secondary breeding sites of this

FIGURE 2—Sunlit river margin with emergent and floating vegetation, a breeding site of *Anopheles farauti* Lav., indicative of the selective environmental individuality of the species.

FIGURE 3—Road ruts, the most important man-made catchments on all occupied island bases in this area, an important stepping stone in the active migration of the species from jungle and stream margins to man's habitation.

2

3

species were created by human activities and these man-made catchments were of paramount importance wherever encountered on military bases in the occupation of the Pacific Islands. Road ruts, lumber trails, ammunition dumps, bomb and shell craters, slit trenches, road-side ditches and coral pits were classic secondary locations utilized by *farauti* for development of its aquatic forms. (Figs. 3, 4) It can generally be said, however, that the adults do not choose by preference collections of water held in factitious containers as tin cans, bottles and tire casings or in natural catchments as tree holes, leaf axils or coconut shells for the deposition of ova and subsequent development of larvae and pupae.

GUADALCANAL

The long, winding, sluggish streams with marginal plant types having high anopheline production potentials provided ideal breeding areas throughout their courses in progressing seaward across the alluvial plains of the northwest coast. Outlets to many streams were blocked by sand bars formed through the pounding action of the surf and the slowly moving streams with poor gradients over-flowed their banks, thus increasing the extent of larval breeding in favorable habitats. These geomorphologic characteristics fulfilled three of the essential criteria aiding to maintain anophelines in specific areas of the South Pacific, i.e., (1) slow moving streams with adequate exposure to sunlight, (2) protective marginal vegetation, and (3) formation of lagoons and swamps at stream outlets.

During continued periods of localized heavy rainfall or frequent showers in the densely wooded, mountainous Kavo Range, eggs, larvae and pupae were not infrequently flushed from these streams, and the aquatic forms were passively dispersed over hundreds of acres of flooded, flat coastal grasslands. Rivers and streams pursuing new courses as a result of suddenly acquired pressure heads frequently cut across the winding loops in the normal course of meandering rivers and streams. With recession of flood waters and subsequent development of flood plains, many loops became isolated from the newly developed channels. Ponds were formed holding residual water and they comprised the "ox-bows" which remained as important breeding areas throughout the year.

The flat open grasslands and accessible coconut groves were repeatedly invaded by military vehicles; porous top soil became packed by vehicular traffic and numerous deep ruts were produced. These semi-permanent catchments were impervious to runoff waters and they were maintained by intermittent rainfall providing ideal conditions for the continued development of large anopheline populations.

FLORIDA ISLANDS

The Florida Islands presented an unusual problem relative to the control of *farauti*. Typical breeding places so well illustrated on Guadalcanal and other islands in the Solomon chain were not abundant. Prominent steep faced coral and limestone cliffs arising from the shoreline and a fine grained, buff colored, clay topsoil were natural barriers in preventing the unnecessary formation of man-made depressions and water catchments. Campsites of military forces were, therefore, limited by nature to a few hundred yards of the coastal area reducing to a minimum the extent of anopheline breeding in these principal invasion sites.

Streams flowing from seepage springs were small, yet within the widely dispersed occupied area of the Florida Islands a total of 122 main branches and prominent tributaries were mapped along the shoreline of Tulagi and Gavutu Harbors, Hutchinson Creek and Purvis Bay. Paralleling the courses of many streams, numerous semi-circular water carved "basins" were formed in the foraminiferal and conglomerate limestone. In periods of diminished rainfall and water flow, these natural basins, holding from one cup to several gallons of water, were im-

FIGURE 4—Improperly graded roadside ditch.
FIGURE 5—Limestone sink.

portant in the seasonal maintenance of anopheline populations. In sunlit areas such typical water pockets were drained by cutting v-shaped openings through the soft limestone while marginal brushing was not encouraged in the densely shaded and heavily overgrown sections of these streams.

In the Tulagi-Florida area, Kuntz (10) reported *farauti* breeding in shaded mangrove swamps with a high saline content. During periods of prolonged rainfall, numerous small streams flooded vast stretches of mangrove swamp along the coast and larvae were flushed into these exceptional water environments where they were capable of completing their aquatic development. Larvae were recovered in heavy densities from pools high in decaying organic debris.

On Tulagi, bomb and shell craters made during the initial stages of the military campaign of the Solomon Islands were of temporary importance as breeding sites. Streams on Tulagi were not large. Their courses were brief and somewhat direct with adequate drainage to the bay. In view of the rapid institution of control measures and the small size of Tulagi and surrounding satellite islands, *farauti* was readily eliminated. This successful campaign in eradicating anophelines from a well-established endemic area marked the beginning of an all-out effort throughout island-bases in the South Pacific to reduce the index of adult *farauti* in nature to a point where autochthonous malaria would not appear in unseeded troops.

RUSSELL ISLANDS

Numerous small streams intersecting the occupied portion of Banika Island were the most important anopheline breeding sites. During periods of diminished rainfall, water held in pot holes formed along many small streams was a prolific producer of larvae. The numerous reservoirs in these dry stream beds supported large populations of larvae and this ecologic habitat was singularly peculiar to stream beds established in the soft limestone formations of the Russell and Florida Islands.

Banika Island was characterized topographically by the presence of numerous large "swallow-holes" or "sinks." These depressions contained water throughout the year, for the levels of drainage were always the same as or below the existing water table. Thus, permanent ponds were produced, being maintained by seepage from the sub-surface water table, intermittent rainfall, and surface run-off. (Fig. 5)

Dense coatings of microscopic aquatic plants resembling the green water bloom in the United States covered the surface of many ponds. Pleuston type plant growths such as the duckweed were likewise very common. It was interesting to observe the repeated absence of mosquitoes, except for an occasional *Culex annulirostris* Skuse., breeding in ponds and fresh water swamps with such basic plant types. Only a rare anopheline was collected in what appeared to be choice breeding sites. Hess and Hall (11) indicated that microscopic plants do not produce adequate intersection lines as those formed by surface mats, leafy erects, carpet or flexuous plants. The production potential of plants promoting the development of mosquitoes appears to be directly proportional to the linear extent of the intersection between plants and any given water surface, other factors being equal. Thus, the relative intersection values of microscopic plants were not compatible for anopheline production.

Water blooms such as the red and green *Euglena* are typically found in water high in nitrogen and carbon dioxide and low in oxygen. This disturbance in acid-base balance beyond the physiologic tolerances normally acceptable to *farauti* may account for the continued absence of this species in these waters. The increase in acidity of water may rest in (1) continual dissolution of limestone by ground waters containing carbonic acids and from plants giving off carbon dioxide during photosynthesis and (2) as a result of interaction of acids formed in the decom-

position of vegetable debris, plants, fruit, coconut husks and coconut fronds.

Although broken patches of duckweed providing adequate intersection lines for anophelines covered many fresh water sunlit swamps on Guadalcanal and the Russell Islands, *farauti* was rarely collected. Bradley (12) indicated that *Lemna* spp. in large quantities causes a lack of activity among chlorophyll-bearing plankton by cutting off sunlight from the water surface. In numerous ponds examined during repeated surveys, members of the *Chlorophyceae* were conspicuously absent. This reduction in food potential, a possible alteration in water chemistry, and the mechanical blanketing effect by dense mats of duckweed are offered as explanations for the continued absence of *farauti* over these water surfaces. Similar ponds, swamps and pot holes have been observed by the author to consistently fail to reveal larvae of this important disease-bearing vector throughout the New Hebrides in spite of their favorable locations near well traveled jungle trails or native villages.

Water surfaces with a predominance of *Lemna* spp. and *Euglena* spp. served as biologic indicators of unfavorable anopheline breeding environments in the Solomon Islands particularly in those ponds and swamps on islands having calcareous crusts as their superficial geologic structure.

New Georgia Group of Islands (Incl. Vella Lavella, Kolombangara, Rendova, Gizo, Ondonga and Vangunu Islands)

Extensive swamp areas surrounding Munda Point were the chief focal points of anopheline dispersal to shell holes, bomb craters and other combat-made catchments. Breeding was extremely heavy in all these man-made depressions as a result of previous occupation by Japanese forces. There were few streams bearing the importance of primary breeding areas such as those encountered on Guadalcanal. Natural breeding areas consisted mainly of shoreline springs, low-lying swamp areas and several small spring-fed streams along Lambeti Beach.

Malaria on Vella Lavella occurred locally and was minimal. Military installations were spread along 30 miles of the southeast coast with campsites restricted to less than three-fourths of a mile from the beach. Numerous streams penetrated the occupied area and one mangrove and several small fresh water swamps were the principal breeding areas. The main road of travel skirted the coast line and roadside pools were continual sources of re-infestations.

A brief reconnaissance of the Vila area of Kolombangara Island revealed *Anopheles* breeding in swamps and lagoons east of the Vila River. During the initial survey, Downs (13) observed large numbers of *farauti* breeding in wooden rice and water tubs left scattered by the Japanese throughout bivouac areas.

Treasury Islands

Typical breeding places of *farauti* on the Treasury Islands have been covered elsewhere by the author(14). Anopheline breeding was limited primarily to sunlit margins of heavily overgrown Soala Lake and stream on Stirling Island. Prompt control of these two sites prior to extensive military occupation resulted in complete eradication of this species from the island. Stirling Island remained anopheline-free for nearly eighteen months. Anophelines were found on nearby Mono Island along the margins of flattened small coastal streams which flowed into Blanche Harbor.

Bougainville

The area under survey on the island of Bougainville was limited to a perimeter of approximately twenty miles along Empress Augusta Bay. The extent of entomologic surveys was limited to five miles inland and these surveys were rarely conducted at elevations over 1000 feet above sea-level. Principal breeding areas

at the time of occupation were along margins of several large streams flowing through sandy terraces of the island. Fresh water swamps and marshes were formed in abundance adjacent to and paralleling the seashore.

Four factors contributed to the formation of these important breeding areas, each of which was amplified due to the geographic features of Bougainville. These were: (1) excessive monthly rainfall, (2) high water table in a porous, volcanic, sandy topsoil, (3) as meandering streams approached the coast, the land became flatter and poorly drained and streams overflowed their banks for considerable distances along their course and (4) the continual, forceful, pounding action of the surf threw up sand bars at the mouths of rivers and streams. This natural blockage produced extensive impounded, shoreline bodies of water free from active tidal action and favorable for the development of *farauti*.

Densely packed algal mats formed floating carpets over much of the exposed fresh water coastal lagoons. Although such floating mats had low production potentials, they were important in extending the anopheline breeding areas into deeper water of these shoreline lagoons beyond zones of marginal vegetation.

The high water table rapidly filled all vehicle-made depressions and man-made foxholes. *Anopheles farauti* Lav. invaded in large numbers such ideal secondary sites and this invasion typified its furtiveness in occupying *in natura* secondary catchments through alteration of surface terrain and vegetative canopies by man.

ADULT HABITATS

Adult female *Anopheles farauti* Lav. appears to be essentially anthropophilic. Collections of this species have rarely been made from sites removed from native villages and huts, or bed-nets and quarters of military personnel. (Fig. 6)

The exact micro-climatic specifications required by this species were not determined. In only several instances have resting adult mosquitoes been collected in nature. The common denominator appears to be living quarters of human inhabitants. There exists a further selective preference in native huts within a single village. Those permanently occupied were excellent catching stations; those abandoned were likewise given up by female adults of *farauti*.

The hours of greatest activity depended to a great extent upon prevailing climatic conditions. After rains and on quiet evenings the adult anophelines were particularly active between the hours of 1700 and 2000.

A study of the active dispersal by flight of this species would indicate that it does not fly great distances over open bodies of water and it does not actively fly over unfavorable topographic or vertical bar-

FIGURE 6—Native hut, an important daytime resting place of *farauti* throughout the British Solomon Islands.

riers such as dense jungle forests, mountains, or the inter-island anchorage channels in the Pacific(15). The maximum efficient flight range, i.e., the distance *farauti* will fly from breeding places in search of a human blood source, is probably not over 800–1000 yards. Surveys of small off-shore islands less than one-half mile from heavy anopheline production sites repeatedly and consistently failed to reveal anophelines.

In view of its anthropophilic nature, *farauti* remains the single, paramount vector of malaria and filariasis. The excellent studies on filariasis in the Solomon Islands by Byrd(16) and Schlosser(17, 18) have indicated the importance of mosquitoes other than *Culex quinquefasciatus* Say to act as vectors of this pathogenic filaria. The role *quinquefasciatus* plays in the transmission of filariasis has been demonstrated to be of little importance or secondary to other species in all areas surveyed from the Samoan Defense, through the New Hebrides and including the Solomon Islands. *Anopheles farauti* Lav. showed a 52 per cent infection rate for *Wuchereria bancrofti* on Guadalcanal. *Anopheles koliensis* may also be considered an important localized vector in nature for of 231 blooded anophelines collected on Guadalcanal, 6.9 per cent harbored various developmental stages of *bancrofti,* and 3 per cent of the total harbored infective stage larvae.

The intimate relation of *farauti* to malaria can be traced through all islands where the disease is known to exist. Although the propensity of *farauti* for human habitations is not as great as that of such strongly anthropophilic species of *Anopheles* as *gambiae, farauti* showed a high susceptibility to infection with malaria in the New Hebrides. Wherever this single species was encountered throughout the New Hebrides and Solomon Islands, malaria was reported in the indigenous population, and high rates of primary infections were reported in unseeded American and Allied combat and support troops.

Summary

(1) Six species of *Anopheles* are known from the British Solomon Islands. *Anopheles farauti* Lav. appears to be the primary vector of malaria and filariasis.

(2) During the dry season, aquatic forms are found typically along margins of sunlit rivers and streams. The most productive man-made breeding areas were: Road ruts, bomb and shell craters, road-side ditches, and logging areas.

(3) During the wet season, eggs, larvae, and pupae were flushed from their well-known habitats and they could be found over a wide variety of water surfaces. In general, water held in tin cans, tree holes, coconut husks and other small receptacles were not favorable for the development of *farauti.*

(4) The topographic features of the oceanic islands in the Australian region greatly limited the extent of larval development and these features provided characteristic ecologic habitats on many of the major island groups in the British Solomon Islands.

(5) The adult females of *farauti* are markedly anthropophilic, and they are readily collected resting in native huts and in bed nets and quarters of military personnel.

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KNOWN FACTORS CAUSING VARIATIONS IN RESULTS OF INSECT REPELLENT TESTS [1]

B. V. TRAVIS [2]

U. S. D. A., Agricultural Research Administration, Bureau of Entomology and Plant Quarantine

Before the work of Granett (1940) techniques for testing insect repellents showed little uniformity. Since that time most investigators have attempted to standardize their methods and, with slight modification, have accepted the method used by Granett. English workers (Christophers 1947) paid special attention to the standardization of testing conditions, and the effectiveness of different materials was compared on the basis of number of bites received at selected intervals rather than on time to the first bite as in the Granett technique. Travis (1947) used this same method of comparison.

Although the results of tests have varied considerably, it has been possible to study and compare these variations and to determine some of the factors causing them. Most of the data presented in this paper were assembled from records at the Orlando, Fla., laboratory of the Bureau of Entomology and Plant Quarantine. These data will help the reader to understand better why there have been such wide variations in the results of tests previously published by the laboratory.

A review of the literature shows that wide ranges in repellent times seem to be a characteristic of tests with repellents against biting insects. Pijoan *et al.* (1946) made some special tests in which the range in repellent time was small, but the urgency of the search for better repellents during the last war did not permit delays to investigate such small variations.

[1] This work was initiated under a transfer of funds, recommended by the Committee on Medical Research, from the Office of Scientific Research and Development to the Bureau of Entomology and Plant Quarantine, and continued under funds allotted to that Bureau by the National Military Establishment. Paper presented before meeting of American Association of Economic Entomologists, Tampa, Fla., December 1949.

[2] Now with Cornell University. The author wishes to express his appreciation for the guidance given him by E. F. Knipling, who was laboratory leader, and for the assistance given by all members of the laboratory in making these tests.

Most of the tests discussed in this paper were made with the standard repellents—6–12, dimethyl phthalate, Indalone, and mixture 6–2–2 (6 parts of dimethyl phthalate and 2 parts each of 6–12 and Indalone). The repellents were applied on research subjects at the rate of ¼ teaspoonful to the arms (elbow to wrist) and ⅜ teaspoonful to the legs (knee to ankle). In laboratory tests only the arms were treated and exposed at intervals of 20 or 30 minutes until a bite was received. In the field both arms and legs were treated and exposed continuously in areas with high insect populations. Normally the tests were not terminated until there was at least a second bite. Under cage conditions the biting rates on an untreated arm were 50 to 75 per half minute for *Aedes aegypti* (L.) and 5 to 20 per half minute for *Anopheles quadrimaculatus* Say. Except for a few tests, field tests against *Aedes taeniorhynchus* (Wied.) and *Aedes sollicitans* (Walk.) were not conducted unless the biting rate was 20 or more per half minute on an untreated leg; rates of 100 + were common. Against *Stomoxys calcitrans* (L.), the biting rates were 38 to 94 per half minute. All materials were evaluated on the basis of the repellent time (time from application of the chemical to the first bite).

Throughout the testing program there was close liaison between the laboratory and Philip Granett, who up to the war period had conducted the most precise repellent tests. When a repellent was compared with the same standard in both laboratories, the repellent ratio was usually the same, even though Granett made most of the tests on his own arms and had long repellent times, and the tests at Orlando were made on the arms of several individuals and the repellent times were shorter.

ARM-AND-LEG TESTS.—In field tests it has been customary to treat both the arms and legs of test subjects to increase the number of materials a given group could evaluate. An adjustment for the difference in the size of the limbs was made by applying one and a half times as much repellent to legs as to arms. Exposures were equalized by having the subjects squat every few minutes and hold their arms at the same level as the legs.

A statistical analysis of the data from the first field trip showed that there were no significant differences in the results obtained on the different limbs. This observation was confirmed by applying Indalone to both arms and legs of six subjects and exposing the appendages to *Aedes sollicitans*. The average repellent time for these tests was 143 ± 18.8 minutes for the arms and 146 ± 19.0 minutes for the legs. The difference required for significance was 44 minutes. The data from other field trips were not analyzed statistically, but at no time were variations noted that could be attributed to the different limbs.

DIFFERENCES BETWEEN SUBJECTS.—Early in the testing program repellents were found to be considerably more durable on some subjects than on others. Perhaps the most striking difference was observed in the tests with dimethyl phthalate against *Aedes aegypti*. Although the average repellent time for dimethyl phthalate was 247 minutes in 3,406 laboratory tests against this species, three subjects were located who were only partially protected. These subjects always received a few bites immediately after treatment. No other extreme differences were observed with any other subject or against any other species of biting insect.

Table 1 includes data from tests against four mosquito species. Since the tests were not made specifically to demonstrate differences between subjects, the 6 subjects analyzed were chosen because they had the largest series of records. Against *Aedes aegypti* and *Anopheles quadrimaculatus* tests with dimethyl phthalate provided data over a 2-year period. During that time the same 3 subjects exposed arms treated with dimethyl phthalate on 20 different days to *Aedes aegypti* and on 28 days to *Anopheles quadrimaculatus*. Against *Aedes taeniorhynchus* no records were available for large series of tests in

which the same subjects were treated with the same repellents; therefore a field trip was selected in which each of 4 subjects was treated with the same 10 repellents. Included in this series were one subject on whom the repellents were effective for only a short time, one subject on whom repellents were very lasting, and two who were considered average. Data on the *Aedes sollicitans* mentioned in the arm-and-leg tests are also summarized.

Repellent time in the *aegypti* tests varied so much that the difference between subjects was just under statistical significance; with *Anopheles quadrimaculatus* the difference between subjects was significant. One subject, however, experienced the shortest repellent time in tests against both *Aedes aegypti* and *Anopheles quadrimaculatus,* the respective averages being 202 and 118 minutes. In the *taeniorhynchus* tests considerable difference existed between subjects, which included two men who usually provided the extremes for the repellent range in a group of tests. One man had an average repellent time of 298 minutes, which was 2.2 times as long as the "short-term" man, who had an average of 133. The greatest difference between men occurred in the *sollicitans* tests, the average repellent time on one man being 267 and on another only 80 minutes.

This chemical had been tested early in the program and was found to show little repellency against *Aedes aegypti.* Since it was a poor repellent and a good organic solvent, it was used to dissolve various solid materials for testing as repellents. After a number of solids suddenly appeared effective, it was discovered that a second lot of this chemical was more effective as a repellent than the first. In three paired tests with the two lots, the first lot gave an average repellent time of only 21 minutes whereas the second was effective for 132 minutes.

REPELLENT TIME BASED ON FIRST AND THIRD BITES.—Although it has been customary to evaluate repellents on the time to the first bite, at Orlando tests are normally continued in the laboratory to the second bite and in the field to the third bite. An analysis of the data, however, indicated that results were only slightly more precise when they were evaluated on the basis of bites subsequent to the first. Therefore all the repellent records are based on the time to the first bite. Data to demonstrate this point are taken from a field trip in which 12 subjects were treated with the same 3 repellents—2-phenylcyclohexanol, 2-cyclohexylcyclohexanol, and a mixture of these two. The average repellent time and standard error to the first bite were 183 ± 20, 148 ± 18, and 173 ± 21; to the third bite 215 ± 17, 200 ± 20, and 201 ± 18. In neither case was there any significant difference in effectiveness between the repellents, and they remained in the same order of effec-

TABLE 1.—Variations in repellent time against mosquitoes on different subjects treated with dimethyl phthalate, except as noted.

Species	*Tests on each subject*	*Average repellent time (in minutes) on indicated subjects*							*Difference required for significance*
		1	*2*	*3*	*4*	*5*	*6*	*All*	
	Number								*Minutes*
Anopheles quadrimaculatus	28	145	118	229	...	...	...	164	49
Aedes aegypti	20	295	202	287	...	...	...	261	61
Aedes sollicitans	4	117	267	147	105	150	80	144	77
Aedes taeniorhynchus [1]	10	298	133	209	208	...	...	212	60

[1] Tests with 10 repellents.

SUBSAMPLE DIFFERENCES. — Although different subsamples of the same chemicals frequently varied in effectiveness, the most striking variation of this type was experienced with two lots of diethyl phthalate.

tiveness regardless of which bite was used for the evaluations. In addition, the variations between tests were only slightly less for the third than for the first bite.

EFFECT OF SWEAT.—In tests made on subjects wet with sweat D. M. Jobbins (personal communication), Pijoan *et al.* (1946), and the Orlando group found that repellent time was much longer on dry skin than on moist skin. In fact the subjects on whom repellents were not durable were usually those with a moist skin; likewise, the repellents were usually more durable on subjects with dry skin.

In comparative tests at Orlando with some of the more promising compounds on sweaty and moist skin, the subjects for the sweat tests remained in an air-conditioned room maintained at 90° F. and 90 percent relative humidity, and exercised at intervals to maintain an extreme sweat condition. These tests were made during July, August, and September of 1945, and because of the prevailing temperatures and humidities there was little difference between the sweaty and the moist skin.

The results with the different repellents against *Aedes aegypti* were too variable to permit a general conclusion (table 2). The greatest reduction in repellent time that might have been attributable to sweating was obtained with diisopropyl tartrate.

With five of the compounds a longer repellent time was obtained on wet skin than on moist skin, but with at least two of these materials, isobutyl sulfone and 2, 5, 7-trimethyl-3-octyne-2, 5-diol, the differences were clearly not significant. Greater differences in repellent time could be expected under more contrasting conditions.

Tests were made against *Anopheles*

TABLE 2.—Protection obtained against *Aedes aegypti* with various repellents applied to wet skin.

Repellent	*Tests on wet skin* [1]	*Repellent time*	
		Average	*Reduction under moist-skin tests*
	Number	*Minutes*	*Percent*
Acetoacetic acid, cyclohexyl ester	8	84	Increase
Anisyl alcohol	4	141	14
Bicyclo [2.2.1]-5-heptene-2,3-dicarboxylic acid, *cis*-, dimethyl ester	6	148	36
Cinnamic acid, isopropyl ester	4	76	38
Cyclohexaneacetic acid, alpha-cyano-, ethyl ester	4	138	31
Cyclohexanecarboxylic acid, 1-hydroxy-, cyclopentyl ester	2	143	6
1,2-Cyclohexanedicarboxylic acid, diethyl ester	4	164	7
m-Dioxane, 4-(*p*-methoxyphenyl)-5-methyl-	4	118	55
1,3-Dioxolane, 2-hexyl-4-methoxymethyl-	4	133	40
1,3-Dioxolane, 5-methyl-5-nitro-2-propyl-	2	150	25
Ethanol, 2,2′-thiodi-, diacetate	4	152	36
Hydracrylic acid, beta-phenyl-, ethyl ester	6	122	40
Hydrocinnamic acid, alpha,beta-epoxy-beta-methyl-, ethyl ester	10	101	47
Isobutyl sulfone	2	158	Increase
dl-Malic acid, dibutyl ester	4	144	63
Mandelic acid, ethyl ester	4	108	52
2-Naphthol, 1,2,3,4-tetrahydro-	3	192	28
3-Octyne-2,5-diol, 2,5,7-trimethyl-	2	187	Increase
Phthalic acid, dimethyl ester	32	91	52
Phthalimide, *N*-butyl-1,2,3,6-tetrahydro-	6	171	Increase
Propionic acid, diester with 1,5-pentanediol	4	137	14
Succinamic acid, *N,N*-diethyl-, propyl ester	2	143	49
Succinamic acid, *N,N*-dipropyl-, ethyl ester	4	153	Increase
Succinic acid, alpha-cyano-beta-methyl-, diethyl ester	2	173	21
Tartaric acid, diisopropyl ester	5	84	65

[1] With most of the materials several times as many tests were run on moist skin as on wet skin.

quadrimaculatus with the same materials, but because the results were so variable it was concluded that sweating made little or no difference on the effect of the repellents.

DIFFERENCES BETWEEN BROODS.—Although the repellent time of a given compound varied considerably in the laboratory, little divergence from the average was seen in the field until the second year of the testing program. In June 1943 the average repellent time was 214 minutes for a total of 35 tests with dimethyl phthalate against *Aedes taeniorhynchus*. A month later, and after a new brood of mosquitoes had emerged, the average was only 50 minutes for 25 tests with the same species and the same repellent. None of the other repellents were very effective against this brood and low repellent times prevailed until another large brood emerged in September. With the September brood, dimethyl phthalate was again effective, with an average of 213 minutes, and the repellent times for other compounds were similar to previous averages. Low repellent times were experienced also with all repellents, including the standards, at least one time in 1944 and in 1945. Biting rates and meteorological conditions were comparable during all these tests. The only explanation that can be given for these variations in repellent times is that the broods of mosquitoes differed in their reaction to repellents.

In the laboratory *Aedes aegypti* showed considerably less variation than *Anopheles quadrimaculatus*. When the average repellent times for 12 bimonthly periods were compared, *Aedes aegypti* had a pooled average of 251 ± 11 minutes and *Anopheles quadrimaculatus* of 134 ± 17 minutes.

Tests were made in which the larvae and adults of *Anopheles quadrimaculatus* were reared and fed in different ways to discover the causes for variations in the repellent times. No encouraging leads were obtained, and from time to time, in spite of any changes in rearing, feeding, and testing techniques, the repellent time would vary widely from the average. Terzian and Stahler (1949), however, reported differences in the biting rates of *Anopheles quadrimaculatus* when they varied (1) the proportions of males to females in the test cages and (2) the population density of the larvae in the rearing pans. Usually the periods of either long or short repellent times extended over several days to several weeks and were not a day-to-day variation.

BITING RATES.—The effect of different biting rates on repellent times was mentioned by Bacot and Talbot (1919) but Granett (1938, 1940) demonstrated that repellent times decreased as biting rates increased, both in the laboratory and in the field. Therefore, repellent tests were not conducted in the Orlando laboratory unless the biting rates were high.

In one series of field tests the standard repellents were used against *Stomoxys calcitrans*, when the biting rate was only 1 to 4 per minute on an untreated leg. Most of the repellents were still effective after 5½ hours, when the tests were terminated. A few weeks later the same materials were tested against a population of flies sufficiently high to give biting rates of 38 to 94 in half a minute. Indalone was the only material that remained effective for as long as 2 hours. Dimethyl phthalate and 6–12 failed in less than an hour.[3]

A similar incident occurred in a field test against *Aedes taeniorhynchus* when biting rates were from 10 to 13 per minute. Tests were made with several mixtures, but the repellent times were far greater than had been expected and most of the tests were terminated without a bite. For example, when treated with 75 percent of Indalone in alcohol, 1 man received a bite within 90 minutes and 2 received none in 148 minutes; whereas, with a biting rate in excess of 20 in half a minute, the average repellent time was 52 minutes. Similar results were obtained with other materials tested at the same time.

[3] Travis, B. V., and Smith, A. L. Unpublished manuscript.

No quantitative studies were made in the laboratory, but it was found impractical to evaluate repellents when the biting rate fell below 10 bites per half minute.

DIFFERENCES BETWEEN SPECIES.—The effectiveness of repellents against biting insects is so variable that one cannot safely predict which materials will be the most effective. In general, however, 6–12 and mixture 6–2–2 have been found superior to dimethyl phthalate and Indalone when used against culicine mosquitoes. The chief value of Indalone is against *Stomoxys calcitrans*. One of the most striking reversals in effectiveness was the poor showing made by dimethyl phthalate against *Anopheles farauti* Laveran in the South Pacific. This material had been selected because of favorable results against *A. quadrimaculatus*. Conversely, 6–12, which was much less effective than dimethyl phthalate against *A. quadrimaculatus*, was much more effective against *A. farauti*. Data taken from other reports being prepared at Orlando illustrate these differences (table 3), and show that there was less variation with mixture 6–2–2 than with any of the other standard repellents.

OTHER VARIABLES.—In field tests the subjects moved about every few minutes so as to be frequently exposed to "fresh" mosquitoes. Although the biting rates on untreated appendages might show little difference between the new and the old location, the mosquitoes appeared to be more avid when first disturbed; the subjects often received punctures on treated appendages immediately after they moved to a new location.

When the data from different subjects were being studied, there seemed to be no significant difference in results due to the size of the arm or leg, in spite of the fact that large limbs received less repellent per unit area than did small limbs. Frequently longer repellent times were obtained on subjects having hairy arms and legs. The arms of one subject, on whom the repellents lasted the longest, were unusually hairy, but this did not account for the long repellent time as the results were the same after one arm was shaved.

SUMMARY. — Data are presented to demonstrate known factors that cause variations in results of insect repellent tests against *Aedes aegypti* (L.), *A. taeniorhynchus* (Wied.), *A. sollicitans* (Walk.), *Anopheles quadrimaculatus* Say, and *Stomoxys calcitrans* (L.). The duration of effectiveness of repellent compounds varied greatly on different persons and also against different species of mosquitoes. The most striking variation of this type was experienced with two subsamples of diethyl phthalate, one lot giving an average repellent time of only 21 minutes and the other 132 minutes. Repellent times also varied with different broods or lots of mosquitoes. Low biting rates caused an extension of repellent time, whereas in tests made on skin wet with sweat the repellent time was decreased.

TABLE 3.—Average repellent times (in minutes) of standard repellents against different species of biting insects.

Species	*6–12*	*Dimethyl phthalate*	*Indalone*	*Mixture 6–2–2*
		Laboratory tests		
Aedes aegypti	331	247	141	271
Anopheles quadrimaculatus	53	108	41	147
A. freeborni Aitken	466	447	274	416
A. punctipennis (Say)	477	447	282	455
A. farauti	388+	43	72	198
Stomoxys calcitrans	101	47	246+	189
		Field tests		
Aedes taeniorhynchus	272	160	145+	243
Mansonia spp.	406	243	...	336
Stomoxys calcitrans	46	38	192+	...

Variations also occurred because the insects were more avid when they were first disturbed. Although the repellent time to the third bite displayed less variability than the time to the first bite, there seemed to be no significant difference between the results obtained with the two methods of evaluation; neither was there a significant difference between arms as compared with legs, or between different sizes of appendages.

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THE TOXICITY OF SEVERAL INSECTICIDE RESIDUES TO MOSQUITOES COMMON IN THE PACIFIC NORTHWEST

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In 1949 laboratory tests were made at the Corvallis, Oreg., laboratory of the Bureau of Entomology and Plant Quarantine to determine the effect of the residues from several insecticides on three genera of mosquitoes common in the Pacific Northwest—*Aedes, Culex,* and *Culiseta.* The results of these tests are discussed in this paper.

Materials and Methods.—The floodwater *Aedes* included *A. vexans* (Meig.) and *A. sticticus* (Meig.) in about equal numbers. These species occur in large numbers in the overflow lands along the Columbia River and its tributaries, and they are easily collected and reared from eggs under controlled conditions. *Culex pipiens* (L.), *C. tarsalis* (Coq.), and *Culiseta incidens* (Thom.) were collected locally from ponds as fourth-instar larvae and as pupae, and were then placed in the insectary, where they emerged. This room was kept at a constant temperature of 80° F. and a humidity of 60 to 70 percent. All tests were made under these conditions. The collection of *Culex tarsalis* included a small number of the closely allied species *C. stigmatosoma* (Dyar), as these two species are difficult to separate.

Two types of tests were conducted—the first to determine the time required to knock down all mosquitoes exposed continuously to a residue, and the second to determine the mortality of mosquitoes exposed to a residue for only 2 minutes. In the knock-down tests the mosquitoes were transferred to holding cages when all of them were prostrate and unable to fly or crawl. This was done to determine whether any of the mosquitoes would recover. In the mortality tests the mosqui-

toes were removed to holding cages after the 2-minute exposure and the numbers down after 1, 2, 4, 6, and 24 hours were recorded; however, only the 24-hour records are given in table 1. In many cases the mosquitoes were down and apparently dead within 1 to 6 hours after exposure.

Wide-mouth quart mason jars fitted with screen-wire lids were used as the test chambers. The inside surfaces were uniformly coated with acetone solutions of the test chemicals by rolling the jars containing them between the hands until the solvent evaporated. All the chemicals except pyrethrum were applied at the rate of 10 mg. per square foot. Pyrethrum was tested alone at 0.1 mg. and also at 0.05 mg. plus 0.5 mg. of piperonyl butoxide. From 10 to 20 female mosquitoes 2 to 11 days old were used per test, and each test was replicated from 2 to 5 times with different lots of mosquitoes. Only the females were used, as males are unreliable test insects. A few days' difference in the age of the males makes a great difference in their susceptibility, and they are much easier to kill than females.

TABLE 1.—Speed of knock-down and mortality of mosquitoes exposed to residues of several insecticides. All except pyrethrum used at the rate of 10 mg. per square foot.

Insecticide	Floodwater *Aedes*		*Culex tarsalis*		*Culex pipiens*		*Culiseta incidens*	
	Time for complete knock-down	24-hour mortality after 2 minutes' exposure	Time for complete knock-down	24-hour mortality after 2 minutes' exposure	Time for complete knock-down	24-hour mortality after 2 minutes' exposure	Time for complete knock-down	24-hour mortality after 2 minutes' exposure
	Minutes	*Per cent*	*Minutes*	*Per cent*	*Minutes*	*Per cent*	*Minutes*	*Per cent*
DDT	36	100	55	89	61	77	44	100
Methoxychlor	47 (2) [1]	83	68	44	101	31	80	100
TDE	56 (8)	68	52	49	58	79	71	100
Fluoro analog of DDT [2]	11	94	12	100	12	100	14	100
Ethoxy analog of DDT	159 (12)	54	351 (4)	...	268 (9)	...	180	...
Benzene hexachloride (12.8 per cent gamma)	27	100	26	97	29	100	23	100
Lindane	21	100	23	100	24	100	15	100
Toxaphene	192	77	202	56	203	69	168	62
Chlordane	67	97	65	89	59	88	64	100
Parathion	22	100	29	100	28	100	24	100
Dieldrin	104	98	92	83	104	100	68	100
Aldrin	68	100	70	100	53	100	56	100
Heptachlor	61	94	61	100	58	100	72	100
Pyrethrins:								
0.1 mg. per square foot	10 (5)	65	11	49	14	84	9 (7)	97
0.05 mg. plus piperonyl butoxide 0.5 mg. per square foot	9	100	17	79	14	91	13	100

[1] Figures in parentheses indicate per cent recovery in 24 hours.
[2] 1,1,1-trichloro-2,2-bis(*p*-fluorophenyl)ethane.

Results.—The results given in table 1 show that *Culiseta incidens* was easy to kill, all except two of the chemicals causing 100 per cent mortality after a 2-minute exposure. However, the knock-down time was not always so short with this species as with the others. The *Aedes* mosquitoes were knocked down faster and killed

easier than the *Culex* with several of the compounds, especially DDT, methoxychlor, parathion, and pyrethrum plus piperonyl butoxide. There was little difference in the susceptibility of the two *Culex* species.

Pyrethrum, the fluoro analog of DDT, parathion, and lindane caused the most rapid knock-down of all the species. The fluoro analog, for example, gave complete knock-down in 11 to 14 minutes whereas parathion required 22 to 29 minutes. However, an exposure to parathion of only 2 minutes in all cases gave 100 percent mortality within 2 hours. Dieldrin, aldrin, and heptachlor were slow to cause knock-down but within 24 hours gave nearly complete mortality. Lindane was one of the most efficient residual poisons on adult mosquitoes. (This is especially interesting since lindane is inferior to many of the other chemicals when used as a larvicide on the immature stages.) The ethoxy analog of DDT was inferior to DDT, the fluoro analog of DDT, TDE, and methoxychlor. Because several of the materials gave 100 percent kill, it is impossible to compare them closely.

MOSQUITO STUDIES IN CHINA, PAST AND PRESENT

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As early as 1828, *Anopheles hyrcanus sinensis* from Canton and *Culex vagans* from Foochow were collected by Trentepohl and described by Wiedemann. Fifty years later, Manson published his classical experiments with mosquitoes on the transmission of *Wuchereria bancrofti* in Amoy. Then a few specimens were collected from time to time by foreign people, such as customs workers, from the chief commercial centers along the coast like Shanghai and Hongkong.

The first check list of mosquitoes reported from China was given by Faust (1926). Since then, Chinese workers also took up the studies of mosquitoes, chiefly on general survey. As noted in Feng's (1938) paper, Li and Wu worked in central China, Chin in northeastern China, Yao in southwestern China and Feng in different parts of China, as well as Riley in Hainan Is., Jackson in Hongkong and Gaschen in Yunnan.

Since the start of the Sino-Japanese War in 1937, the studies on mosquitoes have made great progress and become enlarged in scope to include the bionomics, relation to diseases and control, as well as doing large scale survey work in the interior of China. For example, just on Yunnan-Burma Road and Railway there were five groups working on mosquitoes and malaria: (1) League of Nations Malaria Unit, headed by the late R. C. Robertson, with entomologist T. L. Chang in 1939; (2) U.S.P.H.S. Malaria Mission, headed by L. L. Williams, Jr., with the late Bruce Mayne as entomologist, in 1939–40; (3) Chefang Malaria Laboratory of the National Health Administration in cooperation with the International Health Division of the Rockefeller Foundation, headed by M. C. Balfour and the late W. C. Sweet, with entomologist C. Y. Chow, in 1940–42; (4) Yunnan Provincial Malaria Institute, headed by Y. T. Yao, with entomologist C. C. Wu, in 1940–42; and (5) U.S.P.H.S. Medical Mission, headed by V. H. Haas, with entomologists W. L. Jellison, Gordon Smith, K. C. Chen and F. W. Fisk, in 1941–42. Unfortunately, all the work of the above groups was

stopped by the Japanese invasion of Yunnan-Burma border in May 1942.

After World War II, mosquito studies were centered in Nanking and Taiwan, with the writer in charge. However, since 1949 the work has been carried on only in Taiwan.

I. Taxonomy and Geographical Distribution

Feng(1938) listed 98 species of mosquitoes for China, 24 being anophelines and 74 culicines, representing 12 genera and 22 subgenera. He also gave their geographical distribution. Sweet *et al* (1942) added four *Anopheles* as new records for China: *A. aconitus, A. annandalei interruptus, A. leucosphyrus,* and *A. stephensi.* Yao (1943) added *A. majidi* to the list, but so far as the writer knows, this species occurs only in India. Yao probably had mistaken *A. pattoni* for *A. majidi,* because these two species resemble each other very much. By the inclusion of Taiwan fauna, there is now a total of 39 species of anopheline mosquitoes reported in China. A key to them was made and their geographical distribution according to Feng's publication(1938) was added by Chow (1949, a). Another key to 16 species of *Anopheles* found in Taiwan was also published (Chow, 1949, b).

Bohart(1946) presented a key to 79 species of culicines, adding one genus and seven species to Feng's list(1938). However, he failed to include two of Feng's species. Among the seven species added by Bohart, all except *Culiseta niveitaeniata* and *Culex theileri* need further confirmation. Chow(1949, c) added one genus and 19 species as new to China. Thus up to present, 95 species of culicines have been reported from China (excluding Taiwan fauna), representing 13 genera. The number of species belonging to each genus is: *Megarhinus* 2, *Tripteroides* 3, *Topomyia* 1, *Harpagomyia* 1, *Uranotaenia* 5, *Orthopodomyia* 1, *Ficalbia* 2, *Mansonia* 4, *Heizmannia* 2, *Armigeres* 6, *Aedes* 34, *Culiseta* 1 and *Culex* 33.

II. Bionomics

A general bionomics study of the two important malaria vectors in China, *Anopheles hyrcanus sinensis* and *A. minimus,* was made by Chow(1948). The seasonal prevalence of *Anopheles* in Yunnan was reported by Chow and Balfour (1949). Hu(1935) observed the house-frequenting behavior of *A. hyrcanus sinensis* in Shanghai. At the same locality the blood preference of this species was studied by Toumanoff and Hu(1935), and Chang(1937) studied its egg production. In Chungking, Chow(1949, d) studied the time of feeding of anophelines.

As for culicines, Feng(1937, a) discussed the hibernation mechanism, and Chow(1949, e) observed the breeding habits and hibernation of plant-container mosquitoes. Wang(1938) stated that the anal gills of larvae have no importance for the oxygen absorption, the oxygen in water passing through larval skin, and that the amount of oxygen (either dissolved or free) required for survival was greatest in *Anopheles* and least in *Aedes.*

The resting habits of mosquitoes in the buildings after being sprayed with DDT are now under our observation in Taiwan.

III. Relation to Diseases

A summary of this subject has been given by Feng(1935).

Relation to Malaria: Feng(1937, b) stated that the important malaria vector in Manchuria is *Anopheles maculipennis atroparvus,* in Sinkiang *A. sacharovi,* in north China *A. pattoni,* in central China *A. hyrcanus sinensis* and in south China *A. minimus.* The infection rates of anopheles with malaria parasites both naturally and experimentally were summarized by Yao (1944). Sweet *et al.* (1942) reported that in 26,372 dissections of 13 species of *Anopheles* in western Yunnan, malaria infections were found in *A. minimus* only, with an infection rate of one per cent. In Nanking, the writer was the first to find sporozoites infection in *A. hyrcanus sinensis* in 1948 and thus proved by dis-

section that only this *Anopheles* species in this locality is the malaria vector. In Taiwan we also proved by dissections that *A. hyrcanus sinensis* is important for the plains area and *A. minimus* for the foothill regions.

Relation to filariasis: As mentioned above, Manson discovered that *Culex quinquefasciatus* (*C. fatigans*) was the vector of *Wuchereria bancrofti* at Amoy. Since 1930 the studies on the transmission of filariasis in China were taken up by Chinese workers. Feng(1931) reported that *A. hyrcanus sinensis* caught in nature showed *W. bancrofti* filarial infection and some of the infected specimens had mature larvae. Hu made a series of studies on the susceptibility of Shanghai mosquitoes to experimental infection with *W. bancrofti,* from 1935 to 1939, published in the Peking Natural History Bulletin, and later (1940) with *Microfilaria malayi.* He reported a high susceptibility of *A. hyrcanus sinensis* with both *W. bancrofti* and *M. malayi,* and of *Culex pipiens pallens* and *C. vagans* with *W. bancrofti.*

Relation to dengue fever and Japanese B encephalitis: Little has been done on experimental studies of mosquito transmission of these diseases in China. However, *Aedes aegypti* and *A. albopictus* are rather common in south China and generally believed to be the vectors of dengue fever; while *Culex pipiens* and *C. tritaeniorhynchus* are suspected for Japanese B encephalitis, a small epidemic of which was reported to occur in Peiping.

IV. CONTROL

Hindle and Feng(1929) mentioned the value of local species of fish in China for the destruction of mosquito larvae. In Nanking, Yao and Wu(1935) used paris green as an anti-larval measure. However, before DDT was available, comparatively large scale mosquito control, using paris green, pyrethrum and automatic siphons, was carried out by us during wartime in western Yunnan and Chungking with the help of J. C. Carter of the Rockefeller Foundation. After the war, Carter also helped us with the DDT spraying, both the larviciding in ricefields, and the adulticiding in Nanking and Taiwan. In addition, T. T. Wang of the National Institute of Health in Chungking studied the local emulsifiers for pyrethrum, and T. N. Chen of Taiwan Agricultural Experimental Station tested local materials for insecticides.

V. INSTITUTIONS AND PERSONS WORKING ON MOSQUITOES

1. Chekiang Entomology Bureau, Hangchow: F. S. Li and S. C. Wu—Taxonomy, 1931–35.

2. Fan Memorial Institute of Biology, Peiping: C. Ho—Taxonomy, 1928–30.

3. Hongkong Malaria Bureau: R. B. Jackson — Taxonomy and bionomics, 1931–38.

4. Lister Institute, Shanghai: Stephen Hu and T. L. Chang—Bionomics and experimental infections, 1933–40.

5. Lingnan University, Canton: W. A. Riley and L. Y. Wu—Taxonomy, 1931–36.

6. Malaria Laboratory of the National Institute of Health cooperated with the Rockefeller Foundation, Chefang, Chungking and Nanking: C. Y. Chow—Taxonomy, bionomics and control, 1940–

7. National Institute of Health, Divisions of Entomology and Chemistry, Chungking and Nanking; C. Ho and T. L. Chang—Bionomics; T. T. Wang—Insecticides; 1942–

8. Peiping Union Medical College, Division of Parasitology; L. C. Feng—Taxonomy and experimental infections, 1930–

9. Taiwan Malaria Institute, Chaochow, Taiwan: Established by R. B. Watson and C. Y. Chow in November 1946—General survey, bionomics and control.

10. Taiwan Agricultural Experimental Station, Taipeh: T. N. Chen—Insecticides.

11. Yunnan Provincial Malaria Institute, Mangshih: C. C. Wu—General Survey, 1940–42.

At present, mosquito studies in China seem to be confined to Taiwan. There are only three mosquito men here: T. N. Chen on insecticides; T. L. Chang on bio-

nomics and control; and the writer on the taxonomy of culicines and of mosquito pupae, bionomics and control. A monograph on Taiwan anopheline fauna is in the course of preparation by us. In conclusion, the writer wishes to take this opportunity to thank the IHD of the Rockefeller Foundation and their representatives in the Far East, Dr. M. C. Balfour and Dr. R. B. Watson, for their cooperation, advice, and support, without which the studies of mosquitoes in China could not have made such progress.

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RESISTANCE OF SALT-MARSH MOSQUITOES TO DDT AND OTHER INSECTICIDES [1]

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Studies by members of the Orlando, Fla., laboratory in the Cocoa Beach area of Brevard County, Fla., in the summer of 1949 indicated that aerial applications of DDT at the rate of 0.2 pound per acre and higher were not giving such good control of salt-marsh mosquitoes (*Aedes taeniorhynchus* (Wied.) and *A. sollicitans* (Walk.)) as in previous years. Apparently the mosquitoes in this area, which had been under intensive treatment since 1945, had developed some degree of resistance to DDT (Deonier *et al.* 1950). Other workers have reported on the development of resistance in house flies (King and Gahan 1949) and mosquitoes (Mosna 1947) after several years' exposure to residues of DDT, but so far as is known, there have been no previous reports of mosquitoes developing a resistance to DDT over large areas as a result of aerial spraying. Laboratory tests were made with larvae and adults from treated and untreated areas in Brevard County to compare their susceptibility to DDT, and to evaluate the effectiveness of other insecticides as larvicides and adulticides. The results of these tests are given in this paper.

LARVICIDE TESTS

Tests were made on larvae taken from marshes that had been sprayed intensively with DDT during the last 5 years, and from other marshes that had been sprayed infrequently or not at all. Third- and fourth-instar larvae were brought to the laboratory, where comparative tests were made with acetone-water suspensions of DDT and several other larvicides. Some difficulty was experienced in getting the larvae into the laboratory at the proper stage for the tests. Fourth-instar larvae were desired, but frequently some pupation occurred before the readings were completed. From past experience it was known that the pupae and prepupal larvae are less readily affected by larvicides than younger larvae. Several attempts to obtain larvae from locations in other counties away from control areas were unsuccessful.

Tests with DDT were made against three lots of *Aedes taeniorhynchus* larvae from the intensively treated area, four lots from an untreated area, and two lots from areas that had been sprayed only occasionally. One lot of *A. sollicitans* from the treated area was also tested. The results with DDT, summarized in table 1, indicated that the larvae from the intensively treated area were much less susceptible to this compound than the larvae from elsewhere. Considerable pupation occurred in some tests, but the pupae and old larvae appeared to be more resistant than similar stages from the untreated area.

The mortalities of *Aedes sollicitans* were distinctly lower than those of *taeniorhynchus* from the treated area, in the one test in which no pupation occurred. No larvae of *sollicitans* from an untreated area were available for comparison.

The results of comparative tests with DDT and other insecticides against seven lots of larvae from five different locations are given in table 2. With *Aedes taeniorhynchus* larvae from Cocoa Beach marsh (in the heavily treated area), DDT and TDE gave much lower kills than any of the other five materials. This was also true for DDT with *A. sollicitans* larvae from the treated area, but TDE was not

[1] This work was conducted under funds allotted by the National Military Establishment to the Bureau of Entomology and Plant Quarantine.

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tested against this species. These two compounds gave about the same results as the other materials against larvae from the other marshes. The other materials also gave about as good results against larvae from the treated areas as they did against those from other locations. Parathion was by far the most toxic of any of the materials, as it gave 100 percent mortality at a dosage of 0.001 p.p.m. (one-fifth of the lowest dosage shown in the table) in three of the four tests against *taeniorhynchus*.

TABLE 1.—Tests against fourth-instar *Aedes taeniorhynchus* and *A. sollicitans*, from different locations in Brevard County, in acetone suspensions of DDT. (Average of 2 beakers of 25 larvae each; number of larvae that pupated before end of test shown in parentheses.)

Date	*Location*	*Percent mortality 48 hours after applications of DDT at—*			
		0.05 p.p.m.	*0.025 p.p.m.*	*0.01 p.p.m.*	*0.005 p.p.m.*
		Treated areas (Aedes taeniorhynchus)			
Aug. 26	Cocoa Beach	100	76	44	16
Sept. 1	South Causeway	0 (50)	0 (50)	0 (50)	0 (50)
15	Do.	16 (11)	12 (15)	4 (19)	0 (21)
		Untreated areas (Aedes taeniorhynchus)			
Aug. 5	Titusville Beach	96 (2)	92 (4)	80 (10)	34 (33)
26	Do.	100	100	100	100
Sept. 1	Do.	100	98 (5)	96 (43)	38 (50)
15	Do.	100	100	58 (21)	22 (39)
		Areas occasionally treated (Aedes taeniorhynchus)			
Aug. 19	Shiloh	100	100	96	90
	Haulover	98	98	86	90
		Treated area (Aedes sollicitans)			
Aug. 5	Yoder marsh	48	26	18	0

TABLE 2.—Toxicity of several insecticides in acetone suspensions to fourth-instar larvae of salt-marsh mosquitoes taken from different locations in Brevard County, Fla. (Average of 2 beakers of 25 larvae each; number of larvae that pupated before end of test shown in parentheses.)

Marsh location	*Treatment*	*Percent mortality in 48 hours*						
		DDT	*TDE*	*Toxaphene*	*Dieldrin*	*Lindane*	*Chlordane*	*Parathion*
		0.005 p.p.m.						
Yoder [1]	Heavy	0	...	64	46	58	40	100
Cocoa Beach	do.	16	0	72	56	80	100	100
Haulover	Occasional	90	72	46	52	64	74	100
Shiloh	do.	90	96	64	70	54	90	100
Titusville	None	100	100	100	100	100	100	100
		34 (33)	...	0 (0)	74 (13)	34 (33)	84 (8)	100
		0.01 p.p.m.						
Yoder [1]	Heavy	18	...	86	82	100	92	100
Cocoa Beach	do.	44	4	88	100	100	100	100
Haulover	Occasional	86	92	98	100	96	100	100
Shiloh	do.	96	92	98	100	80	100	100
Titusville	None	100	100	100	100	100	100	100
		80 (10)	...	22 (39)	90 (5)	88 (6)	100	100
		0.025 p.p.m.						
Yoder [1]	Heavy	26	...	98	100	100	100	...
Cocoa Beach	do.	76	8	100	100	100	100	...
Haulover	Occasional	98	98	100	100	94	100	...
Shiloh	do.	100	100	100	100	96	100	...
Titusville	None	...	...	...	...	...	...	...
		92 (4)		88 (6)	100	78 (11)	94 (3)	98 (1)

[1] *Aedes sollicitans* larvae. All others were *A. taeniorhynchus*.

The test in which it failed at this dosage was the one in which prepupal larvae were used. Against *sollicitans* it gave a kill of 80 percent at this dosage and 100 percent at 0.0025 p.p.m.

SPACE-SPRAY TESTS

Tests were made to compare the susceptibility to DDT and several other insecticides of adult mosquitoes obtained from different salt-marsh areas. The adults were reared in the laboratory from fourth-instar larvae or pupae collected from one untreated and two intensively treated marshes in Brevard County, from one treated marsh near Sarasota, and from one untreated marsh in north Volusia County. One of the treated marshes in Brevard County (Yoder marsh) yielded about equal numbers of *Aedes sollicitans* and *A. taeniorhynchus,* but the others showed over 95 percent of *A. taeniorhynchus.*

The space-spray tests against salt-marsh adults were conducted in 100-cubic-foot cabinets, and the procedure normally used in tests against *Aedes aegypti* (L.) was followed closely. Each insecticide was dissolved in cyclohexanone, and 2 ml. of the solution was sprayed into each cabinet. After a settling period of 2 minutes, two cages of mosquitoes were exposed for 10 seconds. Tests against one collection of adults were also made at a 60-second exposure. After completion of the exposures the mosquitoes were transferred to clean cages for 24-hour mortality readings.

In the tests with DDT, table 3, the adults of *Aedes taeniorhynchus* from treated areas were markedly less susceptible than those from untreated areas. The mortalities of one lot of *A. sollicitans* from a marsh in the treated area were still lower than those for *taeniorhynchus* from the same location, but no *sollicitans* from an untreated area were available for comparison.

Five insecticides in addition to DDT were tested at two concentrations against four lots of adult mosquitoes, one lot from an intensively treated area and three from untreated areas. The mortalities are shown in table 4. Like DDT, TDE was much less effective against the adults from the treated area than it was against those from untreated areas, an indication that the adults were about equally resistant to

TABLE 3.—Comparative mortalities obtained in space-spray tests with DDT against adult salt-marsh mosquitoes from different sources. (Exposure of 10 seconds unless otherwise shown.)

Date	Species and location	Average number of mosquitoes per test	Concentration (percent) and sex							
			0.25		0.5		1.0		2.0	
			Male	Female	Male	Female	Male	Female	Male	Female
			Marshes in treated area							
	Aedes taeniorhynchus									
July 18	Yoder marsh (both sexes)	22	..		..		..		91	
	Yoder marsh (both sexes, 60-second exposures)	33	54		62		94		92	
Aug. 5	Yoder marsh	75	15	35	39	6	31	20	64	52
Sept. 1	South Causeway	180	..	..	8	2	51	7	67	11
Aug. 20	Sarasota	115	28	4	38	10	85	27	84	51
	A. sollicitans									
July 18	Yoder marsh (both sexes)	55	..		..		..		42	
	Yoder marsh (both sexes, 60-second exposures)	32	30		38		46		73	
Aug. 5	Yoder marsh	115	32	13	21	13	63	19	89	31
			Untreated marshes							
	A. taeniorhynchus									
Aug. 5	Titusville Beach	195	93	37	96	62	93	65	97	95
	North Volusia County	140	96	71	91	58	100	89	100	99
Sept. 1	Titusville Beach	365	..	..	98	84	100	96	98	98
			Laboratory colony							
	A. aegypti (both sexes)	81	51		94		100		100	

TABLE 4.—Comparative mortalities obtained in space-spray tests with two concentrations of six insecticides against adults of *Aedes taeniorhynchus* from different locations.[1]

Material and concentration	Treated area		Untreated areas					
	South Causeway		Titusville Beach				North Volusia	
	Sept. 1		Aug. 5		Sept. 1		Aug. 5	
	Male	Female	Male	Female	Male	Female	Male	Female
0.5 percent								
DDT	8	2	96	62	98	84	91	58
TDE	4	0	87	30	86	52	93	54
Toxaphene	40	3	87	26	91	8	93	25
Lindane [2]	71	76	97	49	90	74	87	49
Technical benzene hexachloride	9	0	76	47	78	16	78	26
Chlordane	16	2	73	29	86	40	75	24
2.0 percent								
DDT	67	11	97	95	99	98	100	99
TDE	13	0	99	74	97	93	97	90
Toxaphene	83	28	91	54	99	79	97	92
Lindane [2]	100	100	100	100	100	100	100	100
Technical benzene hexachloride	92	75	98	53	100	90	96	65
Chlordane	95	84	94	57	99	86	99	67

[1] The approximate numbers of specimens (both sexes) in the different series were as follows: South Causeway 190; Titusville Beach, Aug. 5, 200; Titusville Beach, Sept. 1, 365; and North Volusia 150. From 40 to 50 adults per cage were exposed in each test. The figures in the table are percentages killed.

[2] Lindane used at concentrations of 0.25 and 1.0 percent instead of 0.5 and 2.0 percent.

TDE and DDT. At the lower concentration (0.5 percent), the other materials also showed less toxicity to the mosquitoes from the treated area, but at the higher concentration (2 percent) this difference was not in evidence, except possibly with toxaphene. Lindane, although tested at only half the concentrations of the other materials, was the most effective against the resistant mosquitoes, followed by chlordane and technical benzene hexachloride (12 percent gamma isomer). Against mosquitoes from untreated areas, lindane and DDT were the most effective, with TDE third and the others only slightly less effective. Technical benzene hexachloride at a concentration of 2 percent was somewhat more effective than lindane at 0.25 percent, an indication that the technical material is slightly higher in relative toxicity than the 1 to 8 gamma ratio.

RESIDUE TESTS

Tests were made with adult salt-marsh mosquitoes from two of the lots in the previous space-spray tests—one lot from a treated area and one from an untreated area—to determine their relative susceptibility to DDT. One of the lots was also tested on residues of lindane, technical benzene hexachloride, toxaphene, chlordane, and TDE. Each chemical was applied as a wettable-powder spray to plywood panels at the rate of 25 mg. per square foot, and the mosquitoes, confined under petri dishes, were exposed on each treatment for different periods of time. In the first series of tests *Aedes aegypti* adults from the laboratory colony were included for comparison.

As shown in table 5, *Aedes taeniorhynchus* from the intensively treated areas (Yoder marsh) required much longer exposure to DDT than those from an untreated area (Titusville Beach). The exposure times required to produce 50 percent mortality (LT-50) as determined from the test data, were 61 minutes for the former and 10 minutes for the latter, or about six times as long. The LT-50 for *Aedes sollicitans* from the treated area was 111 minutes, or about 1.8 times that for *taeniorhynchus* from the same location. The LT-50 for *A. aegypti* was only 2.5 minutes.

TABLE 5.—Residue tests on three species of adult *Aedes* exposed to DDT spray deposits of 25-mg. per square foot on plywood panels. Mosquitoes from Yoder marsh collected on July 18, and those from Titusville Beach on August 7. (Two dishes of insects at each exposure on two consecutive days.)

Species and place collected	*Average number of mosquitoes per test*	*Percent kill of mosquitoes 24 hours after indicated exposure (in minutes)*								*Calculated time (in minutes) required to produce mortalities*		
		1	*5*	*10*	*20*	*30*	*60*	*120*	*240*	*LT-50*	*LT-70*	*Slope coefficient*
A. taeniorhynchus												
Titusville Beach (untreated)	88	26	29	48	73	75	100	100	..	10	16	2.59 [1]
Yoder marsh (treated)	30	2	18	33	34	34	36	67	96	61	99	2.42 [1]
A. sollicitans												
Yoder marsh (treated)	53	7	0	4	4	10	19	43	93	111	150	3.93
A. aegypti												
Laboratory colony	107	22	74	88	95	96	100	100	..	2.5	4.7	1.9

[1] 1-minute exposures omitted in computing the regression line.

In the tests with six insecticides against *Aedes taeniorhynchus* adults from an untreated marsh (table 6), lindane proved the most effective material, causing 100 percent mortality after a 1-minute exposure. DDT, chlordane, and technical benzene hexachloride each caused complete mortalities with 60-minute exposures. Benzene hexachloride was not tested at a shorter exposure period, so its minimum lethal time was not indicated. Exposures of 60 minutes to toxaphene and TDE produced mortalities of 85 and 78 percent, and the next higher exposure time, 240 minutes, caused 100 percent mortality. It is probable that a 2-hour exposure would have been close to the minimum lethal time for these two materials.

SUMMARY

Studies in the Cocoa Beach area of Brevard County, Fla., in June 1949 showed that the usual aerial treatments with DDT were not giving such effective control of either the larvae or the adults of salt-marsh mosquitoes (*Aedes taeniorhynchus* (Wied.) and *A. sollicitans* (Walk.)) as in previous years. It was suspected that these species had developed a resistance to DDT after 4 or 5 years of intensive spraying operations, and laboratory tests with larvae and adults from several treated and untreated marshes were made to compare their susceptibility to DDT and other insecticides. DDT and TDE gave much lower kills of larvae from frequently treated marshes than toxaphene, dieldrin, lindane, chlordane, and parathion, but gave about the same results as the other materials against larvae from untreated areas. In one comparative test with larvae from treated areas, all the insecticides except parathion showed distinctly less toxicity to *A. sollicitans* than to *A. taeniorhynchus*. Parathion was by far the most toxic material against both species.

In space-spray tests DDT and TDE were much less effective against adults from treated areas than against those from untreated areas. Lindane was the most effective material against the adults from treated areas, followed by chlordane and technical benzene hexachloride (12 percent gamma isomer). Against adults from untreated areas, lindane and DDT were the most effective materials, with TDE third, and the others only slightly less effective. As with the larvae, the mortalities of *Aedes sollicitans* adults were lower than those of *A. taeniorhynchus*.

In residue tests adult *Aedes taeniorhynchus* from treated areas required much longer exposure than those from an untreated area, the LT-50's being 61 minutes and 10 minutes, respectively. Against

TABLE 6.—Residue tests with different insecticides against adult *Aedes taeniorhynchus* collected from an untreated area (Titusville Beach) August 7. (Chemicals applied to panels at the rate of 25 mg. per square foot.)

Chemical	*Exposure period (minutes)*	*Number of insects*	*Percent kill in 24 hours*		
			Male	*Female*	*Both sexes*
DDT	1	68	45	17	26
	5	62	50	19	29
	10	75	74	27	48
	20	109	91	60	73
	30	121	81	70	75
	60	88	100	100	100
	120	96	100	100	100
Chlordane	1	51	57	75	73
	10	73	66	54	60
	60	99	100	100	100
	240	63	100	100	100
Toxaphene	10	89	32	28	29
	60	96	90	80	85
	240	73	100	100	100
TDE	10	88	59	32	39
	60	69	88	74	78
	240	62	100	100	100
Lindane	1	66	100	100	100
	10	45	100	100	100
	60	54	100	100	100
Benzene hexachloride (12% gamma isomer)	60	56	100	100	100
	240	39	100	100	100

adults from an untreated area, lindane was the most effective residue, followed by DDT and technical benzene hexachloride.

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DDT IN ALCOHOL AS A LARVICIDE FOR *AEDES AEGYPTI* CONTROL

BY BRUCE E. SASSE *

The introduction of DDT as a larvicide in campaigns for the extermination of *Aedes aegypti* in Peru has produced extraordinary results in reducing both the time required to eliminate the mosquito from a given area and the over-all expense. In field practice, a saturated solution of DDT (approximately 2 per cent) in 95 per cent ethyl alcohol is added to household water containers in the proportion of 1 cc. to each 6 liters of capacity of the containers. The solution is applied by pouring it from a graduate onto the surface of the water or by swishing it onto the sides and bottom of the container, if empty. This does not affect the potability of the water or its use for other household purposes.

While this method, arbitrarily adopted by the Peruvian National Yellow Fever Department to avoid delay, proved to be highly successful, it left unanswered such questions as minimum effective dosage, preferred method of application, influence of the material of the containers used, etc. To place the larviciding program on a more scientific basis, therefore, the following studies were carried out under laboratory conditions.

The small coastal town of Chilca, some 65 kilometers south of Lima, was selected for the experiments because of its nearness to Lima, its high *aegypti* index and the fact that DDT had not been employed in this community. Two rooms were secured in a typical adobe house for carrying out the studies. All of the DDT-treated containers were kept in one room, and the control containers as well as the stock of larvae in the other. Larvae were collected from nearby natural sources the day before they were needed in the studies and placed in a large barrel provided for this purpose.

The containers were treated only once, at the beginning of each experiment. The larvae were introduced on the same day, and at weekly intervals thereafter. In each experiment the water was changed weekly, before the introduction of additional larvae.

EXPERIMENT No. I: To determine the minimum DDT dosage (quantity of a 2 per cent DDT-alcohol solution) necessary for the treatment of baked clay receptacles containing water.

The common 6-liter capacity terracotta jars were filled with water. The dosages ranged from 0.5 to 7 drops per liter of water. The latter figure is roughly equivalent to the dosage of 1 cc. per 6 liters of water which was being successfully used in the field at this time.

Since the dosage of 0.5 drop was seen to be ineffective, it was discontinued after the third week. The dosages of 1 to 7 drops began to kill the larvae during the first six hours and a 100 per cent kill was obtained at 36 hours for a period of 5 weeks. After the fifth week and through the eleventh week the DDT continued to give excellent results at 42 hours.

It is noteworthy that such a small dosage as one drop per liter of water capacity should be so rapidly and uniformly fatal to larvae for well over a month, and that its lethal effect should be so prolonged as to prevent pupation throughout the 11 weeks of observation, although the jar was emptied and refilled with water each week.

Although nearly equal results were secured by the various dosages, Figure 1 does make apparent the more reliable effects of the heavier dosage of 7 drops per liter of water.

EXPERIMENT No. II: To determine the effect of various types of containers on

* Staff member of the International Health Division of The Rockefeller Foundation, New York, New York.

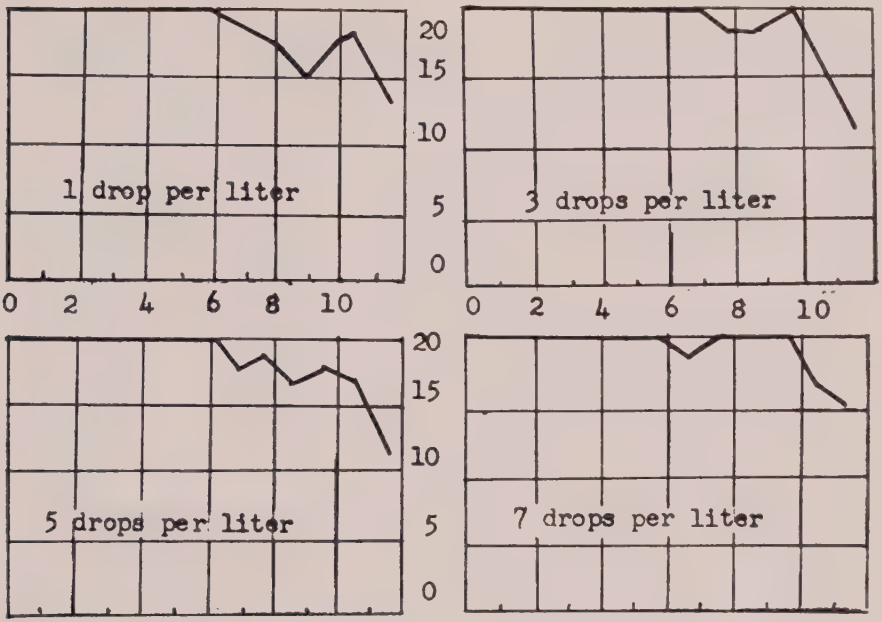


FIGURE 1. Comparison of mortality 36 hours after exposure of 20 *A. aegypti* larvae (vertical scale) placed in container treated with different amounts of a 2% DDT-alcohol solution per liter of water. Larvae introduced each week for 11 weeks (horizontal scale).

the residual action of DDT when applied to the water in the proportion of 1 cc. of 2 per cent DDT-alcohol solution to 6 liters of water. This dosage as well as the method of application is standard practice in the field.

Four of the most common types of containers used along the coast of Peru were selected. These containers were: 1) a small baked clay jar, 2) a large baked clay jar, 3) a concrete-lined tub and 4) a wooden tub (Figure 5).

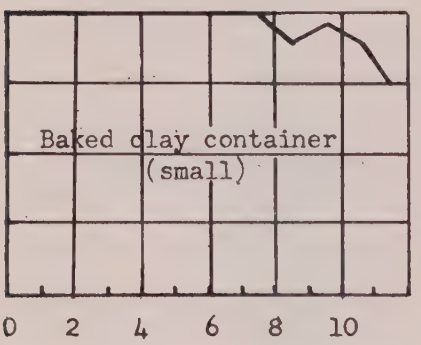
The action of the DDT was practically the same in all containers and the type of material used in the construction of the containers was therefore of no importance. Although a 100 per cent mortality at 36 hours was obtained only for the first 6 or 7 weeks, the subsequent reduction in the toxicity was not marked and a high mortality was secured throughout the 11 weeks reaching 100 per cent in all cases at 42 hours.

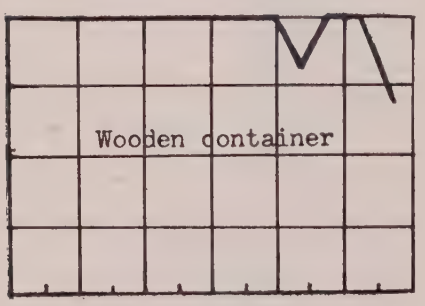
The results obtained in this experiment are presented in Figure 2.

EXPERIMENT No. III: To determine the effectiveness of DDT applied by rinsing the container with a 2 per cent DDT-alcohol solution. The amount of solution used depended on the size and kind of material of the container and was not measured, the excess being poured out.

In this test the following containers were used: 1) large baked clay urn, 2) small baked clay urn, 3) wooden barrel, 4) concrete-lined bucket (Fig. 5). After these containers were rinsed with a 2 per cent DDT-alcohol solution, they were partially filled with water and larvae introduced at weekly intervals.

The results were practically the same as those obtained in experiment No. II, so that this method has no advantage. Field practice is to treat all receptacles which might become *aegypti* breeding





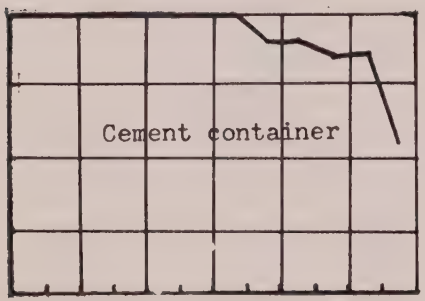
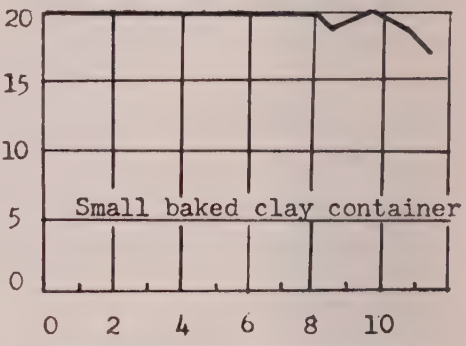
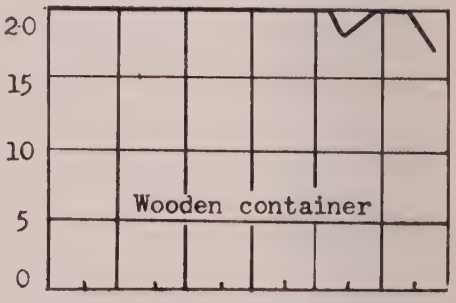


FIG. 2





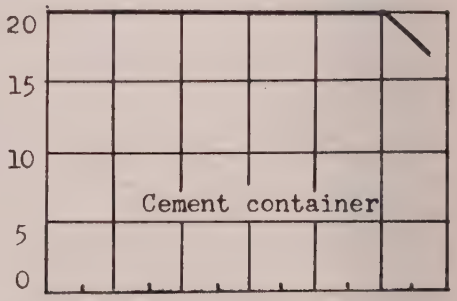


FIG. 3

FIGURE 2. Comparison of mortality 36 hours after exposure of 20 *A. aegypti* larvae (vertical scale) placed in containers of different materials treated with DDT by the addition of 1 cc. of a 2% alcohol solution per 6 liters of water. Larvae introduced each week for 11 weeks (horizontal scale).

FIGURE 3. Comparison of mortality 36 hours after exposure of 20 *A. aegypti* larvae (vertical scale) placed in containers of different materials treated by rinsing them with a 2% DDT-alcohol solution. Larvae introduced each week for 11 weeks (horizontal scale).

places by pouring in the proper amount of DDT solution whether they contain water at the time or not. The action of the DDT at 36 hours became less effective by the 8th week but continued to be 100 per cent effective at 42 hours throughout the experiment. Figure 3 illustrates this gradual decrease in toxicity at 36 hours over the weeks.

EXPERIMENT No. IV: To determine the variation in killing time of DDT over a period of weeks when the DDT is applied in the form of a 2 per cent DDT-alcohol solution in the proportion of 1 cc. per 6 liters of water. The solution was added directly to the surface of the water as is the practice in the field.

In this test one large baked clay urn was treated and larvae introduced at weekly intervals thereafter, and the mortality noted at 2-hour intervals.

Although the larvae did not begin to die until after 2 hours, evidence of toxicity was noted before the first hour had passed. The larvae were moving more slowly and remained on the bottom of the container, unable to rise to the surface for air.

During the first two weeks after treatment the action of the DDT was intense during the first 8 hours, and thereafter with minor variations it continued to be 100 per cent toxic at 24 and 36 hours.

Figure 4 reflects the gradual decrease in the speed with which the DDT acts, due probably both to passage of time and to the weekly changing of the water.

EXPERIMENT No. V: To determine the effectiveness of treating baked-clay jars with DDT several months prior to placing them in service.

Small baked clay urns were rinsed with a 2 per cent DDT-alcohol solution and placed in storage (away from direct sunlight) for 13 and 14 weeks, respectively. The urns were then filled with water and larvae introduced at weekly intervals to observe the toxicity of the DDT.

In the first container which was tested 13 weeks after treatment no toxic action was noted at 24 hours during the first 2 weeks of testing. Before testing again during the third week of the experiment (15th week after treatment), the container was washed with water to remove the dust film which had collected during the weeks in storage. The container became toxic after washing and continued to be 100 per cent effective at 36 hours until the 19th week after treatment and 100 per cent effective at 48 hours through the 23rd week.

The second container employed a week later also proved nontoxic until washed, after which the DDT proved effective in practically the same degree.

By comparison of this with the other experiments it is evident that some toxicity was lost during the storage period, but the possibility is suggested that jars might be treated advantageously in certain situations at the time of manufacture.

SUMMARY OF RESULTS

1. Under laboratory conditions, 1 drop of a 2 per cent DDT-alcohol solution per liter of water is as effective as 7 drops per liter of water in preventing the larvae of *A. aegypti* from developing into adults in household water containers for a period of at least 11 weeks.
2. The material of the containers used to hold water for domestic purposes in the rural areas of the Peruvian coast (baked clay, wood and cement) does not influence the residual action of DDT against *A. aegypti*.
3. The method of application is not important. The same results were obtained by rinsing the containers with a 2 per cent DDT-alcohol solution and by adding the 2 per cent DDT-alcohol solution to the water in the containers in the proportion of 1 to 7 drops per liter of water.
4. The 2 per cent DDT-alcohol solution begins to affect *A. aegypti* larvae within 1 hour of contact, weakening the larvae to such an extent that they

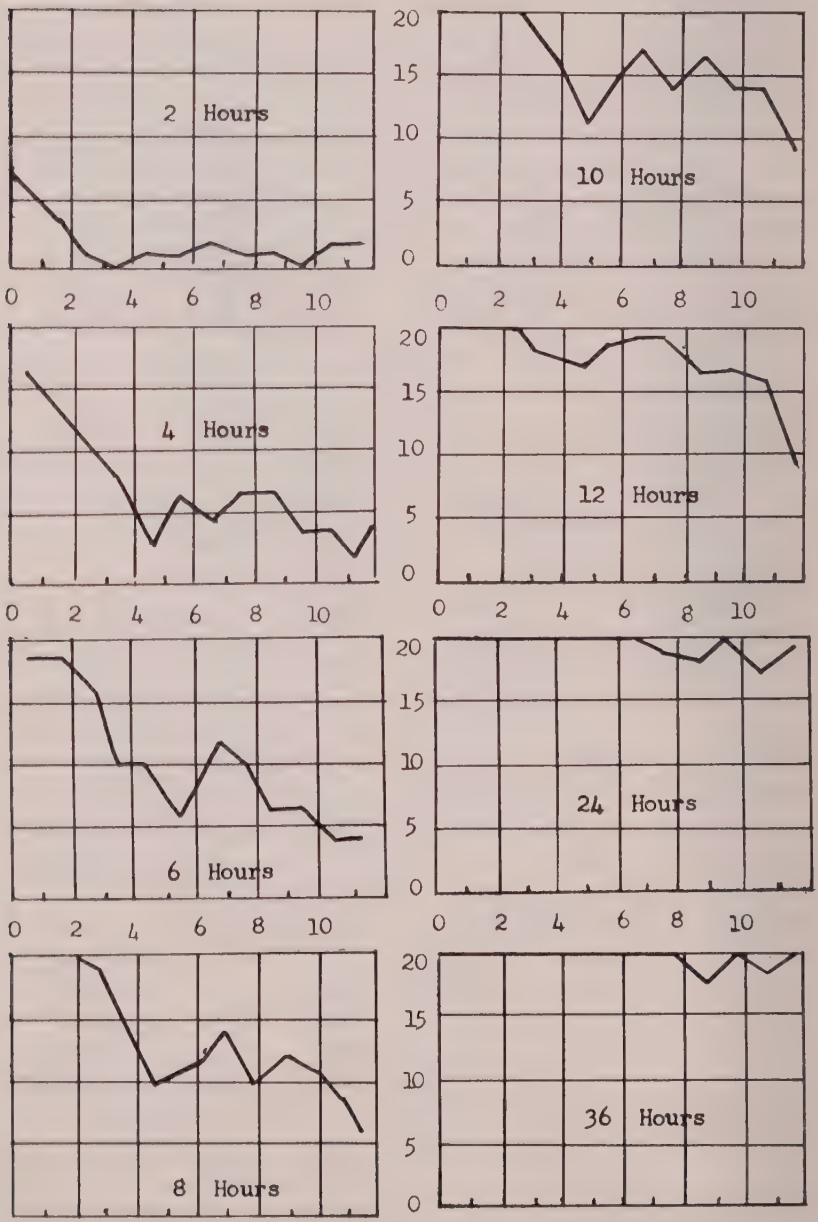


FIGURE 4. Comparison of the killing rate of DDT at different intervals between 2 and 36 hours over a period of 11 weeks (horizontal scale) when applied one time at the rate of 1 cc. of a 2% DDT-alcohol solution per 6 liters of water. Twenty larvae were introduced each week.

Figure 5. Group picture including each type container used in experiments 2 and 3.

begin to die after 2 hours and within 36 hours 100 per cent mortality can be expected. Actually during the first few weeks after treatment the time necessary for a 100 per cent kill is much shorter.

5. The baked-clay container which is the most common type employed in the rural areas can be treated and stored for at least 14 weeks provided it is first washed with water to remove the accumulated film of dust before being used.

CONCLUSIONS

1. A 2 per cent DDT-alcohol solution can be used as a larvicide in *A. aegypti* control with advantage over former methods because of its prolonged residual action and economy of application.
2. In our judgment the recommended dosage is 1 cc. of a 2 per cent DDT-alcohol solution per 6 liters of water capacity, even though under laboratory conditions it was shown that smaller amounts were equally effective. The above dosage assures a greater margin of safety and the amount of DDT is still so very small that it does not represent a danger to the health of the people.
3. Based on the results of the various experiments, the interval between treatments could be extended to 6 weeks. Nevertheless for routine field work it is recommended that a cycle of 4 to 5 weeks be employed to provide a margin of safety.

NEWS AND NOTES

ADVANCE NOTICES OF MEETINGS

PRELIMINARY ANNOUNCEMENT OF THE CLEVELAND MEETING OF THE AAAS DECEMBER 26-30, 1950. The 117th meeting of the American Association for the Advancement of Science, the annual meeting for the year 1950, will be a full scale meeting—with programs in every principal field of science from astronomy and botony to, and including, zoology. All 17 of the Association's sections and subsections, and more than 40 participating societies and organizations, are completing plans for an aggregate of more than 200 sessions.

There will be a considerable number of outstanding symposia. The list of special sessions includes the AAAS Presidential Address, and addresses sponsored by the Academy Conference, the National Geographic Society, the Scientific Research Society of America, the Society of the Sigma Xi, and the United Chapters of Phi Beta Kappa.

An extensive series of tours to museums, laboratories, and industrial plants of the Cleveland area has been planned. Some of these will be of particular interest to chemists and are being included as a part of the program of Section C.

The Annual Science Exposition, in the Arena of Cleveland's Public Auditorium—with some 180 booths—will be almost twice as large as that of the New York Meeting. In the Exposition, publishers, supply houses, microscope manufacturers, instrument makers, and industrial concerns will exhibit their latest products and portray their technical accomplishments on a scale impossible at a smaller meeting in a single scientific field. Adjacent to the exhibit area will be the Main Registration, the Visible Directory of Registrants, the annual Photography in Science Salon, sponsored by *The Scientific Monthly* and the Smithsonian Institution, and the Science Theatre—throughout the week, repeating programs of the most recent scientific films.

Sectional programs which may be of particular interest to AMCA members are those of the member societies in Section F, including:

American Society of Parasitologists, Dec. 27-29.
American Society of Protozoologists, Dec. 27-29.
American Society of Zoologists, Dec. 27-30.
Society of Systematic Zoology, Dec. 27-29.

There will also be two sessions on insecticides under Section C Chemistry—on December 30. The detailed program has not yet been announced but the sections on medicine and agricultural science will probably also include programs of interest to AMCA members. More detailed information will appear in *Science* and *The Scientific Monthly*, and the editorial office of *Mosquito News* will also receive information on special sessions and programs.

The hotels of Cleveland have pledged themselves to provide ample housing for those attending the 117th Meeting. Housing will be taken care of by the experienced personnel of the Cleveland Convention Bureau, with hotels confirming reservations directly. Announcements and coupons for reservations will appear in *Science* and *The Scientific Monthly*. The hotels include the Statler (headquarters of the AAAS), the Hollenden, the Carter, the Allerton, the Olnsted, and the Auditorium Hotel—the last particularly convenient for exhibitors.

THE AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS AND THE ENTOMOLOGICAL SOCIETY OF AMERICA will hold their annual meetings in Denver, Colorado, December 18–21 inclusive, the former with headquarters at the Cosmopolitan Hotel and the latter with headquarters at the Shirley-Savoy Hotel.

A PRELIMINARY NOTICE OF THE 1951 ANNUAL MEETING of the American Mosquito Control Association has already appeared in *Mosquito News*, March, with an additional notice giving more details in a letter from Dr. S. S. Fuller which appeared in the June number.

THE 1951 MEETING of the California Mosquito Control Association is to be held at the Mission Inn, Riverside, California, March 12–14, 1951. For complete information write Richard F. Peters, Executive Secretary, CMCA, 2180 Milvia St., Berkeley 4, Cal. T. D. Mulhern

MAYOR DOROTHY MCCULLOUGH LEE, AMCA member from Portland, Oregon, was unable to attend our recent Conferences, but in a letter dated June 2, wrote, in part, as follows:

". . . Dr. Don Rees, of Salt Lake City, was certainly most helpful to me when I was trying to set up our mosquito control program here in Portland in the beginning. In fact, he even

shipped some mosquito fish to us here, and they have done quite nicely and have been most useful in controlling mosquitoes in the many ornamental pools that abound in our city. I wish I had some real news to tell you about mosquito control work here in the Portland area. However, I think that we are carrying on the same type of program that we have now for about 3 or 4 years, and it is proving quite effective. For the flood-water type of mosquitoes that we have around this season of the year, we do almost all our control work by the use of an aerosol spray dispersed by two airplanes which the City of Portland owns. Later in the season, we have the *Culex* and *Anopheles* mosquitoes, and we treat those largely by aerosol truck and an information service which we give to householders, and also with the aid of the mosquito fish which we place in ponds upon request. All in all, I think our mosquito program is going along quite satisfactorily.

"I am sorry I haven't been able to attend any other meetings of the American Mosquito Control Association. I haven't even been able to get to Berkeley to attend the California Conference there since I have become Mayor. The job of being Mayor of a city the size of Portland is a very confining one, and it leaves me practically no time to get out of town to attend interesting Conferences. However, I hope that things won't always be quite so confining, and that I will be able to meet with the 'mosquito fighters' before too long." H. L. T.

DR. F. C. BISHOPP has been in Hawaii studying Oriental fruit fly work, and while there he addressed a group of more than 75 persons, concerned mainly with various public health activities, on July 14.

He stressed the tremendous importance of mosquito control in fighting mosquito-borne diseases, and described a new fixed aerosol system tested on MATS planes based in Honolulu. Dr. Bishopp also congratulated Dr. Stephen Hu (another active AMCA member) and his staff on their teamwork. (Condensed from the *Honolulu Star Bulletin,* July 15, 1950.)

READERS OF MOSQUITO NEWS may be interested in knowing that I had an opportunity to see some of the thoroughgoing antimosquito work directed by our good friend Dr. Stephen M. K. Hu on the Island of Oahu. Not only was the work of Dr. Hu and his splendid force of mosquito control men highly interesting, but Dr. and Mrs. Hu contributed much to the delightful 4-week visit Mrs. Bishopp and I had to the Enchanted Isles. One of the most interesting and pleasant occasions was a suki yaki party on the beach attended by the members of the Hui O'Makika Mosquito Control Organization. Following a swim in the Pacific and a bountiful, tasty meal, the group presented an informal entertainment of singing and hula dancing. Mrs. Bishopp was duly decorated with a beautiful orchid lei and I was elected an honorary member of Hui O'Makika and presented a certificate of membership signed by the advisors, officers and members and a handsome monkey pod (wood) dish suitably inscribed.

We were assured that one or more members of Hui O'Makika will be with us at the annual meeting in the Riverside District. The esprit d' corps of the Hawaiian workers is most stimulating and gives assurance of effective antimosquito work in Oahu. F. C. B.

THE FOLLOWING AMCA MEMBERS have been appointed to the Insecticide Panel of the World Health Organization: T. H. G. Aitken, J. M. Andrews, G. H. Bradley, A. D. Hess, C. W. Kearns, F. W. Knipe, K. D. Quarterman, and H. H. Stage. These are 5-year appointments. H. L. T.

Salt Lake City, Utah
July 26, 1950

TO THE AMCA MEMBERS:

As many of you know, we are driving from Washington, D. C. to San Francisco, California, primarily to visit two other entomologists, Ernestine Thurman and her husband Deed C. En route, we have stopped in Salt Lake City and have gathered some news which we hope will interest other mosquito workers.

Professor Don Rees, as a member of the Board of Directors of the Salt Lake City Mosquito Abatement District and President of the Utah Mosquito Abatement District, is much involved in the mosquito control problems of this area. And so, this Associate Editor took a "busman's holiday."

Today, at headquarters of the UMAD, we met Bert Wilkins, Manager, and Jim Smith, Field Supervisor. They ushered us into a room where large maps, approximately 3' by 5', dominated. These maps, studded with red, green, and yellow-headed pins, are revised daily according to the field inspectors' reports. Red-headed pins (emergencies) indicate the location of 3rd and 4th instar larvae and pupae; green, 1st and 2nd instars; and yellow, completed treatments. It was interesting to note the scarcity of red-heads.

Gambusia are used extensively to control breeding in the 1,600 ponds found in the private residences of the city. The UMAD maintains propagation pools for the mosquito-eating fish; and we saw one supplied by natural hot water from a nearby hill for year-around rearing.

A system of drains honeycombs the Salt Lake Valley, with 3 main canals draining into Great Salt Lake.

We observed several examples of changes wrought by mosquito control. A once uninhabitable marsh is now the site of a 1,000 house unit, made possible not only by mosquito elimination but by the necessary water removal.

The success of one gnat control project was impressive. Since there is to be a paper published soon, we shall say only that pretreatment and larviciding have virtually eliminated this pest

(Leptoconops kertezi var. *americanum)* which was causing tremendous losses in manpower (impaired efficiency and resignations) in a large industrial plant. H. L. T.

Oakland, California
August 4, 1950

To The AMCA Members:

We have just completed a 3-day tour of the San Joaquin Valley, where we visited some of the mosquito abatement districts, and you might enjoy some highlights. After getting acquainted with the staff of the Bureau of Vector Control, of which Arve Dahl is Chief, Dick Peters very graciously suggested and conducted our trip. Dick, with his charming wife, Helen, drove to Fresno, where Tommy Mulhern, and his lovely wife (also a Helen) took over for the Bakersfield expedition.

East Side Mosquito Abatement District at Modesto was our first stop en route to Fresno. There we met E. Chester (Chet) Robinson, Manager; Allen and Yates, Inspectors; Mrs. Aleta Freitas, Secretary; Franklin Davis, Entomologist; and Marvin Johnson, City Inspector. Section survey maps are used in this District of 283 sq. miles. These maps are 8 inches square, each of one mile in detail, and are made up in the winter by the men who will do the control work the following summer. In this way, the men become familiar with the breeding areas, while providing a permanent record of projects. About 1,200 acres of land previously completely under water have been reclaimed.

At Turlock, the Mosquito Abatement District is a 1,000 sq. mile district. We met Manager G. Edwin Washburn, who, with his outfit of 23 men and Secretary Billie Crawford, posed for a kodachrome. Just across the yard, we visited headquarters of the Central Valley Mosquito Ecology Investigations, a project devoted to the study of *Aedes* ecology, under Deed C. Thurman. The staff included Jack Prescott, Bettina Rosay, Bill Trimmingham, Jim Bray (a new AMCA member), Dick Husbands, and Grafton Campbell. (The "hot" subject is the use of radioactive isotopes in flight range studies.) Just as we were departing, one of the men brought in a quart jar filled with mosquitoes taken with 90 sweeps of a net from an experimental plot in an uncontrolled study pasture. Subsequent count disclosed that there were 25,000 *Aedes nigromaculis* in that jar.

A large impounded fresh water lake was observed at the north end of the City of Madera. This lake formed in a stream bottom from excess water from Friant Dam, is being watched for mosquito breeding by the Madera Mosquito Abatement District, Gus Augustson, Manager.

Tommy Mulhern, Vector Control Specialist, is located at Fresno, where we stopped for the night. You will be happy to know that he and Helen and his 3 boys have a typical California ranch-type house complete with redwood trim, a collie dog, and a cat. We also had the pleasure of meeting Earl Mortenson, Entomologist and co-worker with Tommy, and his wife—again a Helen!

On down the valley the next day, with Tulare Mosquito Abatement District the first stop. Rolland Henderson is Manager of this 562 sq. mile District. We met Janie Oakes, Sec., Eugene Mathias, Entomologist, and Doyle Smith, Foreman. Tulare's budget is one of the lowest per square mile of any of the mosquito abatement districts in California, and notwithstanding the outfit is noted for doing one of the State's most remarkable control jobs. We observed, also, Janie's blond hair, Rolland's picturesque shirt, and learned of Eugene's silver cup won as a golf trophy. (Gene played at Lake Tahoe with Bob Hope.) We thought these unusual facts interesting enough to substitute them for the more important, prosaic mosquito control accomplishments.

Art Geib, Manager, met us at the Kern Mosquito Abatement District, 886 sq. miles, headquartered in Bakersfield. This District was formed in 1917 from 48 sq. miles. Most of the problems in the Kern District are due to agricultural practices; and a public relations man works full time making contacts and attempting to secure agricultural conditions which will facilitate permanent mosquito control. In the city, 90 miles of gutter must be sprayed every two weeks. As to *Gambusia,* Art says, "We couldn't operate without them." Three planes are used in the District, one for reconnaissance and two for spraying. A pilot is employed full time; he maintains his planes, makes his reports, and is consulted by the field men, who are free to call on him directly whenever they deem his assistance necessary. A separate crew operates in the urban area, controlling *C. tarsalis,* the principal vector of encephalitis.

Encephalitis is under study at the Encephalitis Laboratory, University of California, School of Public Health, and Hooper Foundation, which is located about 2 miles across the city from the Kern Mosquito Abatement District. Dr. W. C. Reeves is in charge, and we met, also, Dr. A. C. Hollister, Dr. W. A. Longshore, Mrs. Eva French, and Dr. George Humphrey; "Barney" Brookman, Entomologist with CDC, was not there, but we heard of his Ph.D. thesis which has been completed on the biology of *Culex tarsalis.* Studies on the biologies of other local species are in progress. Bill Reeves' greatest accomplishments at present appear to be avocational, in the fields of carpentry and painting; a complete reconstruction and refinishing job has been done on the lab buildings.

Dusk had fallen when we stopped at Selma. This is where Consolidated Mosquito Abatement District with its 1,000 sq. miles meets its many and varied problems under the managership of Ted Raley. This area is decentralized; there are many more sub-depots here than in any other district, with consequent need for more coordination by the Manager.

Bright and early the next morning, we arrived at the Fresno Mosquito Abatement District, ahead of its genial Manager, Ed Davis. Secretary, Mrs. Edna Lowe, however, took over, and explained some of the work being done in the 302 sq. miles. Ed Davis, who joined us soon, said that the greatest recent event in the District was the visit of Dr. F. C. Bishopp! It may be added here that one of the problems of Ed's outfit is the unknown flight range of pasture *Aedes*. Tree hole mosquitoes are a headache, too.

And then with a whizz, we found ourselves in and out of Yosemite, and on to Merced and Manager Ed Smith's 1,995 sq. miles. Bonnie Findley, Secretary, and Stan Blake, Administrative Assistant, greeted us. The photographic lab is one of the best equipped we encountered on our trip. One of Ed's troubles is the 20 sq. miles of gold dredger pits in which breed all 21 species of mosquitoes ocurring in the District. Three small planes are used for spraying.

No more districts were visited that evening. Instead, we hurried on almost 80 miles to Oakland to spend the night at the home of Ernestine Thurman, Entomologist, Bureau of Vector Control, and her husband D. C., Entomologist, U. S. Public Health Service. H. L. T.

ALAMEDA COUNTY MOSQUITO ABATEMENT DISTRICT, HAROLD F. GRAY, ENGINEER AND MANAGER. We visited representative areas in his district of 445 square miles. At the laboratory we met Theodore Aarons, Assistant Manager and Entomologist, L. Percy Mapes, Division Foreman, and Koichi Onishi, Assistant Entomologist (Onishi is one of Dr. Rees' boys and also one of the famed 442nd Japanese American combat group). The chief interest at present is the dyeing of *Aedes squamiger* with Rhodamine B for flight studies. *Culiseta* biology studies are also under way.

Out at the south end of the District we observed a large area of reclaimed salt marsh where *Aedes dorsalis* is the primary pest. At the end of the day we found ourselves in a field being flooded by a duck club and here were Herbert Brown, Division Foreman, Ivan Best driving the tractor, and Ree Hardesty on the "Weasel."

Finally, at 1-A Court House, we found the Administrative Offices of the MAD, presided over by Miss Margaret A. Prefontaine, Secretary, and Mrs. Lucille Groberg, Accountant.

A very pleasant inspection trip. Recommended to all ACMA members. H. L. T.

DR. ROBERT H. MCCAULEY, JR., should be addressed now at: Communicable Disease Center, P. O. Box 477, Manning, S. C. Dr. McCauley was transferred from the Savannah, Ga., station, February 1 of this year. His abstract on Gammexane may be found elsewhere in this issue.

H. L. T.

COMMANDER JOHN D. DECOURSEY has changed his address. He and his wife and two children moved to North Carolina in July. Commander DeCoursey was with the Bureau of Medicine and Surgery, Washington, D. C.; but now he is engaged in research on insects of medical importance at the U. S. Navy Medical Field Research Laboratory, Camp Lejeune, North Carolina.

H. L. T.

DR. AYROZA L. GALVAO, of São Paulo, Brazil, has been in this country during the past year, taking courses in Public Health at Columbia University, New York City. Dr. and Senõra Galvão were in Washington, D. C. in 1948, when they attended the 4th International Congresses. Their pictures were in the December, 1948 issue of "Mosquito News." Dr. Galvão, planning to return to Brazil in August, visited the National Institutes of Health at Bethesda, Md., in June of this year; and we convey to his fellow members in AMCA, his greetings. He planned to stop at the Agricultural Research Center in Beltsville, Md., and other institutions in Michigan, Ohio, and Georgia, before taking his leave of the United States. H. L. T.

THE WIFE OF DR. L. W. HACKETT died suddenly from a heart attack on August 1, 1950 in Berkeley, California. Dr. Hackett, now retired from the International Health Division, The Rockefeller Foundation, has recently moved to Berkeley and purchased a home there.

H. F. Gray

CHANGE OF ADDRESS. After June 15, 1950 our address will be changed from Calle Viena 26, Mexico 6, D. F., Mexico, to the following:

Calle Londres 45
Mexico 6, D. F.
Mexico.

Wilbur G. Downs, M.D., Rockefeller Foundation, International Health Division, Oficina de Especialización Sanitaria, S. S. A.

EDITORIAL SECTION

Dear Friend:

The Good Neighbor Club of the American Mosquito Control Association is requesting contributions to purchase volumes of MOSQUITO NEWS to be sent overseas to key libraries which were destroyed by war. The addresses of a number of deserving libraries have been furnished us by the Rockefeller Foundation.

You will note that every penny of your money goes into the Treasury of the American Mosquito Control Association. This is possible because the Club has made arrangements with the International Exchange Service of the Smithsonian Institution here in Washington to mail them at no expense to us.

Every dollar contributed to the Good Neighbor Club will do triple service:

1. Add to our country's Good Neighbor policy.
2. Help restore libraries in every part of the world.
3. Aid the American Mosquito Control Association's treasury and prestige.

Where individuals do not wish to contribute separately, will you try to secure small collections which will be credited to your office. All contributions will be acknowledged in MOSQUITO NEWS. We hope to have a complete report by October 1 for inclusion in the December number.

Please make your checks payable to the American Mosquito Control Association and send them to H. H. Stage, Bureau of Entomology and Plant Quarantine, Washington 25, D. C.

THE GOOD NEIGHBOR CLUB
Dorothy McCullough Lee,
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Washington, D. C.

ASSOCIATION NEWS

The American Mosquito Control Association Field Trip Through the New England States

Bertram I. Gerry
Massachusetts State Reclamation Board

A summer field trip, through the New England states for members of the American Mosquito Control Association, started at Hotel Garde in New Haven, Connecticut at 9.30 A.M. on Tuesday, 11th of July and terminated on Saturday, 15th of July at Brandon, Vermont.

During the first day of the tour, Mr. R. C. Botsford, Engineer for the Connecticut Mosquito Control Commission, exhibited a diked salt marsh and discussed the manner in which effective mosquito control is accomplished through water level manipulation. This was followed by a demonstration of the SCAVEL, a device for ditch cleaning, invented by Mr. Botsford. After a luncheon, the group traveled by automobile to Rhode Island where Mr. William Bartosewitz, State Mosquito Control Supervisor, reviewed mosquito control operations on the salt marsh located in the vicinity of Mt. Hope Bay. The motorcade then continued on to Cape Cod where an old-fashioned clambake topped the first day's activity.

On the second day, Mr. Oscar Doane, Superintendent of the Cape Cod Mosquito Control Project demonstrated, at a cat-tail fringed pond in Provincetown, their technique for collecting *Mansonia* larvae and also the Cape Cod method for control of the *Mansonia* nuisance. After a quick look at some of Provincetown's best known landmarks, the party proceeded to the Plymouth Airport to witness a helicopter spraying and dusting demonstration. This was followed by an inspection of the Marshfield-Duxbury Great Marshes (Fig. 1.) where greenhead fly control work had been completed within the previous two days. Immediately upon arrival, Mosquito News Editor Collins of the New York Science Service, with a nose for news, ferreted out an expiring greenhead fly, and called upon his collaborators for a diagnosis. No one will ever know how many cadavers the "Herr" Doctor collected while unobserved, or how many he smuggled out of Massachusetts. In the evening, participants gathered at the Hotel Commander, in Harvard Square, Cambridge, for dinner and a general discussion of the exhibits including their significance.

Early Thursday morning, Mr. Robert Armstrong, Superintendent of the East Middlesex Mosquito Control Project led the group to a dewatered area known as Purgatory Swamp and located in the city of Newton. This area, consisting of about seventy acres of stagnant water containing an abundant cat-tail growth, is immediately adjacent to the Charles River. However, drainage to the river cannot be effected because the water level in Purgatory Swamp is several feet lower than that of the river. In 1949 a lift pump was installed between Purgatory Swamp and the Charles River. The Swamp was then ditched and the surplus water drained into a sump under the pump house. As the sump fills, the pump goes into operation automatically, lifting the water and discharging it into the river. At the same location, Mr. Armstrong demonstrated a rather unique type of flat bottomed river boat equipped for use in the shallow water

Figure 1. Group viewing Marshfield - Duxbury great marshes in Massachusetts where greenhead fly control work is being carried on.

Figure 2. Boat equipped with spray unit. Propulsion furnished by forced stream of water from same pump used in spraying.

areas along the Charles River where *Anopheles* breeding occurs. (Fig. 2.) Propulsion is furnished by discharging water at the boat's stern. This forced stream of water is derived from the same pump which is used for spraying. The party then traveled by automobile to Pittsfield, in the western part of Massachusetts, where the Berkshire County Mosquito Control Project operates. After a short rest in the hotel lounge, the more sturdy adjourned to the American Legion Home where dinner was served in a private dining room. As the evening progressed, it became increasingly evident that Roy Wilson, Superintendent of the Morris County Mosquito Extermination Association of New Jersey, had not the slightest acquaintance with a well-known adage, namely, "no souls are saved after the first five minutes," for brother Wilson continued proselyting throughout the evening. The fact that the Pittsfield dinner was the high point of the entire tour was due in no small degree to "Parson" Wilson's zeal.

On Friday, or the last day of demonstrations, the group left Pittsfield about 8.00 A.M., and enroute to Vermont, inspected a series of beaver dams located in Williamstown, Mass. Because beavers are protected by the State of Massachusetts and cannot be molested, and because these animals can replace their dams nearly as fast as man can destroy them, a drainage program for a beaver inhabited area is impractical. As an alternative, these wet areas are kept under constant surveillance and the borders treated whenever mosquito breeding becomes evident. After a luncheon at Manchester, Vermont, the group proceeded to the town of Proctor, where at the insistence of "Chris" Williamson, the extensive marble collection of the Proctor Marble Works received a brief but thorough perusal. Upon arrival at Brandon, Vt., Mr. John Scott, Mosquito Research Engineer of the Vermont Department of Agriculture, demonstrated a mist blower unit used for mosquito control in the vicinity of Brandon. Later in the afternoon, the party continued on to Lake Dunmore where Mr. Scott, and Mr. Harold Bailey, Deputy Commissioner of Agriculture, explained the manner in which a TIFA fogging unit, and a small three hundred pound hand propelled mist unit, are utilized in the protection of the several boys' and girls' camps located along the shores of Lake Dunmore. About 6.00 P.M. all adjourned to the palatial home of Miss Shirley Farr for cocktails. In the evening, dinner was served at the Brandon Inn. Those attending included Miss Farr and Mr. and Mrs. Landon, who represent the principal sponsors of the Brandon mosquito control program.

Throughout the trip, Mr. Maxmilian Stallman, Commissioner of the Essex County Mosquito Extermination Association of New Jersey, acted as mentor for over-exuberant youth and also guided the party through the social mazes. Since this was the first New England tour of its kind ever attempted, those involved in its organization were somewhat apprehensive of success due to possible conflicts with peak season operations. However, it soon became evident that an inspection of project activities during the summer provides, (1) a greater insight into the individual problems of the various projects and (2) a better understanding of the varying methods used in attacking and solving these problems.

NOTICE

CERTAIN NUMBERS OF "MOSQUITO NEWS" are out of print, and needed to complete sets of this journal now in the hands of libraries. Any member having copies of these out-of-print numbers which he does not need is urged to contribute or to sell them to the Association. They will be paid for at the rate of $1.00 per number if sent, accompanied by a bill, to Secretary-Treasurer, AMCA, 334 Rowell Bldg., Fresno, Calif.

The numbers needed are V1#1, V1#2, V1#4, V3#1, V7#2, V8#1.

Thomas D. Mulhern, *Sec.-Treas.*

REVIEWS AND ABSTRACTS

STUDIES OF THE BIOLOGY AND CONTROL OF BITING FLIES IN NORTHERN CANADA. By C. R. Twinn, Arctic, 3(1)14–26. 1950. Canadian arctic and subarctic species of mosquitoes, black flies, and Tabanids were studied. Observations were made relative to species association, seasonal development, abundance, and characteristic activities of the individual species. At Fort Churchill, Manitoba, 11 species of *Aedes* and 2 species of *Culiseta* were collected including immature stages of all except *A. spencerii* (Theo.) and *Culiseta impatiens* (Wlk.). Sixteen species of black flies were recorded for this region, the major pest species being *Simulium venustum* Say; also 17 species of tabanids including 10 of *Hybomitra,* 5 of *Chrysops* and 2 of *Atylotus.*

Similar studies were conducted at Goose Bay, Labrador where 15 species of mosquitoes were obtained. These included 10 species of *Aedes,* 2 of *Culiseta,* 1 of *Culex,* 1 of *Wyeomyia,* and 1 of *Anopheles.* Also 12 species of black flies, the dominant species being as follows: *Simulium perissum* D. & S. (49%), *Simulium venustum* (35%), and *Prosimulium hirtipes* Fries (11%). Seventeen species of tabanids were taken in the same region including 9 of *Hybomitra,* 1 of *Atylotus,* and 7 of *Chrysops.* Additional records are cited for Whitehorse, Y.T., Baker Lake, N.W.T., Algonquin Park, Ont., northern British Columbia, and the Yukon.

Chemical control studies indicated the superiority of DDT as a mosquito larvicide—0.2 or 0.25 lb. of DDT in oil constituting a practical dosage for prehatch and posthatch treatments of *Aedes* larvae. Prehatch dosages of 0.05 to 0.35 lb. per acre showed little if any residual larvicidal effect after one year. Immature stages of black flies were controlled by a DDT-fuel oil solution at a concentration of 0.1 p.p.m. maintained for 15 minutes at the point of application. Dosages of 0.39 p.p.m. for 24 minutes or 0.113 p.p.m. for 16 minutes proved to be dangerous to fish life when the DDT concentrate was not diluted with oil.

Standard repellents, i.e., dimethyl phthalate, Rutgers 612, and 6:2:2 mixture gave protection for 5 to 6 hours against mosquitoes. As a rule repellents gave longer protection against black flies than against mosquitoes, but none appeared to be effective against tabanids. Wide mesh headnets impregnated with dimethyl phthalate provided good protection against mosquitoes but were penetrated by black flies. These studies are being continued.—B. I. Gerry, State Reclamation Board, Boston 8, Mass.

THE DURATION OF THE AQUATIC STAGES OF *Anopheles minimus,* THEO., DETERMINED BY A NEW METHOD. By C. R. Ribbands. Bull. Entom. Res. 40:371–377. 1949. In Assam the duration of aquatic stages of *Anopheles minimus* in nature was determined by daily dipping each foot of a 100 foot stretch of stream bank for a two month period. In spite of great variation in the stream level due to monsoon rains, and subsequent variation in the daily totals collected, an analysis of the sequence of peaks of the various instars showed that the duration of larval life was seven days. This is a shorter period than expected, since floating cage experiments had previously indicated a 9–12 day larval life for this species.

The life cycle of *Anopheles minimus,* under monsoon conditions in Assam, probably occupies 14 days; egg 2 days, larva 7 days, pupa 2 days, and adult to first egg laying 3 days.—Harold R. Dodge, Communicable Disease Center, Atlanta, Georgia.

STUDIES ON THE ACTION OF DDT ON ANOPHELINE MOSQUITOES AND HOUSE-FLIES. By A. N. Johnston. Bull. Ent. Res. 40(Pt. 3):447–452. 1949. Experimental results indicated that the mortality rate of Anophelines depends on the time of exposure. No evidence of differential reaction between the various stages of larvae was found.

Definite and positive evidence of the action of DDT on mosquito pupae was obtained.

Laboratory trials indicated that mortality of adult Anophelines following contact with DDT is relatively slow, and the period of exposure required for a lethal dose is approximately 15 minutes.

Adult flies required a much shorter period of exposure, viz., 30 secs., and the rate of mortality was higher. Evidence of the mechanical transference of DDT by flies is also presented.—Author's summary.

MOSQUITO CONTROL: AN INVESTIGATION OF NATURAL SURFACE FILMS IN RELATION TO THE SPREADING OF LARVICIDAL OILS UPON WATER. By B. A. Toms. Bull. Ent. Res. 40(Pt. 4):503–510. 1950. The first section of this report is given over to discussion of what is expected in the way of spreadability of a larvicidal oil and some of the methods used to determine these factors. He separates surface films into biological or mineral types, depending on the nature of the material, and outlines some of the reasons spreading may be effected by such films. Preliminary measurement is done by measuring "spreading pressure" which is the force in dynes per centimeter that must be opposed to the advance edge of the drop just to prevent it from spreading on a clean water surface. The additional resistance offered by the surface film is given as film pressure, which is a force equal in magnitude to the spreading pressure of an oil which just fails to spread on the contaminated surface. Using the method of N. K. Adams as a basis for study, he prepared known concentra-

tions of oleyl alcohol in purified liquid paraffin, in one series, and terpineol and liquid paraffin in another. These were diluted in such a manner as to give a difference in film pressure of 5 dynes. Using these prepared solutions in the field, a survey was made along the Gold Coast limited by the towns of Sekondi and Axim covering an area of about 15 miles. By making field tests on a representative selection of standing water, he was able to determine the average spreading pressures for the area, and thus determine in advance the best type of oil that would give maximum coverage on all the types of standing water to be treated. This method of predetermining the most satisfactory type of base oil with or without wetting agents seemed to produce excellent results in determining more effective larvicidal solutions.—Franklin C. Nelson, Standard Oil Co., Linden, New Jersey.

PUPAE OF THE NEARCTIC ANOPHELINE MOSQUITOES NORTH OF MEXICO. By George Henry Penn. Jour. Nat. Mal. Soc., 8(1):50–69, 1949.

PUPAE OF THE ANOPHELINE MOSQUITOES OF THE NORTHEASTERN UNITED STATES (DIPTERA CULICIDAE). By Richard F. Darsie, Jr. Rev. de Entomologia, 20(1–3):509–530, 1949.

In the first paper, Penn describes and illustrates 14 species of *Anopheles,* including the Mexican *A. aztecus* in view of its close relationship to American forms. The descriptions are concise and easily followed, and a tentative key to the species treated is provided. The system of chaetotaxal nomenclature proposed by Knight and Chamberlain is used throughout.

Darsie in the second paper describes, illustrates and keys out the 7 species of *Anopheles* known to occur in the northeastern portion of the United States. The system of chaetotaxal nomenclature followed is that of Baisas, as modified by Penn.

It seems unfortunate that these two papers should appear at approximately the same time, as all the species treated by Darsie are also described by Penn. To most American workers, Penn's paper probably will prove of greater value because of its wider scope. Darsie's study is not without value, however, for the variations in hair size and branching he records are from different specimens, with a few possible exceptions, than those used by Penn. These observations are given in two tables. While these tables are convenient and well planned, they could be improved by indicating the number of specimens of each species studied. For instance, a range of 6–11 branches of a particular hair in a small series of 3 or 4 specimens lacks the significance of a similar range in a much larger series.

Penn wisely calls his key to species a "tentative" one, for with the limited number of specimens of known identity available at the present time for comparison and study, some of the hair characters used eventually may be shown to be unreliable. He had, for instance, as few as 6 specimens of *A. albimanus* and 3 of *freeborni.* Darsie worked under similar handicaps.

Both Penn and Darsie are to be complimented on their initiative in laying a firm groundwork for future American anopheline pupal study. It is hoped that others will realize the value of pupal characters in mosquito taxonomy, associate pupal exuviae with adult specimens, and put the keys to test. The time is probably not far off when the taxonomist will be able to key out anopheline pupae to species with somewhat the same assurance that he now determines larvae.—Roy W. Chamberlain, U. S. Public Health Service, Montgomery 7, Alabama.

ALTURA DE POUSO DAS FÊMÉAS DE ANOPHELES DARLINGI E DE ANOPHELES AQUASALIS NAS PAREDES INTERNAS DAS CASAS. L. M. Deane and R. G. Damasceno. Revista do Serviço Especial de Saûde Pûblica 11(2):503–506. 1948. 1. In order to verify the vertical distribution of the resting females of *Anopheles darlingi* and *Anopheles aquasalis*—the main vectors of malaria in the Amazon—on the inside walls of dwellings, night captures were made between April 1947 and October 1948 in several types of rural houses in Belém, Maracana, and Capanema, State of Pará, Brazil. The walls of these houses were ruled off in horizontal divisions one meter wide from the ground up.

2. It was found that the females of both species are distributed in decreasing numbers from the lowest to the highest levels, that the majority are found on the two lowest divisions, and that few specimens are encountered above three meters—1.4% of 7,151 *darlingi* and 2.1% of 3,137 *aquasalis* in the observations herein reported. It was also found that the engorged females show a tendency to rest at a lower level than the unfed females.

3. It is concluded that in the control of malaria by indoor spraying with DDT in areas where the vectors are *darlingi* and *aquasalis,* it is sufficient to apply the insecticide up to 3 meters, disregarding the higher portions of walls and ceiling, thus saving considerable material and working time.—Authors' summary.

FURTHER STUDIES ON THE LOSS OF INSECTICIDES BY ABSORPTION INTO THE MUD AND VEGETATION. By A. B. Hadaway and F. Barlow. Bull. Ent. Res. 40(Pt. 3):323–343. 1949. (Colonial Insecticide Research, Uganda, Africa.) Formulations of DDT have been applied to standard mud blocks. Toxicities to *Glossina palpalis* and *Aedes aegypti,* and the proportions of insecticide recovered from an outer layer of approximately 0.1 mms. thickness have been compared.

Absorption of DDT in oil solutions was considerable and amounts recovered from the outer layer were only from 8–19% of the total dosage applied. Adsorption of the insecticide from the oil on to mud occurred. There was some correlation between the capillary rise of the solvent and the extent of absorption. Toxicities of the blocks to test insects were low.

Using concentrations of 2%, 5%, and 10% in

power kerosene, there was no increase in the proportion held on the surface. Application of excessively heavy dosages increased the amounts in the outer layers but there was a trend towards greater absorption, and therefore to greater waste, at the high dosages. Repeated applications similarly built up a larger dosage in the outer layer but did not increase the proportion there.

Emulsions were intermediate between solutions and wettable powders as regards absorption and toxicity.

Up to 77% of the insecticides applied as wettable powders was recovered from the outer layer, and toxicities were correspondingly high. When benzene hexachloride wettable powder was used there was rapid loss of benzene hexachloride from the surface by volatilisation. After 15 days the dosage had decreased considerably and the percentage in the outer layer had fallen from over 70% to 20%.

Loss of DDT by penetration of the carrier oil through the leaf cuticle may occur when an oil solution is sprayed on to vegetation. The extent of penetration varies with different plants.

There is an indication that small amounts of DDT are transferred from the inside of treated leaves to other untreated parts of young coffee and avocado pear plants.

Deposits of DDT on leaves exposed to ordinary climatic conditions remained toxic to tsetse flies for a longer period when applied as an emulsion than as an oil solution. Deposits from a water suspension of a wettable powder were washed off readily by rain.

There is some evidence that continuous exposure to sunlight produced some chemical change in, and reduced the toxicity of, DDT deposits applied to glass plates as a solution in kerosene. —Authors' summary.

A REVIEW OF THE SPECIES OF CULEX OF THE SUBGENUS MELANOCONION (DIPTERA, CULICIDAE). By Lloyd E. Rozeboom and William H. W. Komp. Ann. Ent. Soc. America 43(1):75–114, pls. I-XV, 1950. The purpose of this paper is to make possible the determination of members of this subgenus, which, as treated by these authors, includes both *Melanoconion* and *Mochlostyrax*. Since this determination must be entirely dependent, for most species, on details of the male terminalia, the keys and figures are confined to this group of structures. Ninety-one species are keyed and figured and eleven other species listed but not treated further because of insufficient knowledge. An alphabetical list is given of the keyed species with the original literature references, type localities, notes on types with certain lectotype designations, and recent and new synonymy. The authors discuss the necessity for dissecting the terminalia in order to study it properly and the difficulties involved in the study of types not properly prepared. Using the key and the excellent illustrations together and using proper techniques in preparing the material, one should have little difficulty in recognizing the described species. Some difficulty may be experienced in interpreting the shape of the clasper. To the reviewer it seems rather unfortunate that a better term could not be found than "snout-shaped" in describing the clasper in the section *Choeroporpa*. Snouts are of such varied shapes that it brings nothing very definite to mind, and the clasper of *aikenii* seems fully as "snout-shaped" as that of *paracrybda* or *intrincatus*, while that of *elephas* seems simple. If the clasper of *latisquama* is considered simple then that of *elephas* should be, the former appearing considerably more modified than the latter. One might also think that the clasper of *zeteki* had a distal portion expanded. It is to be hoped that when the immature stages and the biologies of the species become better known a more satisfactory grouping of species can be found than this based upon the shape of the male claspers. The paper is an excellent one, however, and should greatly aid the study of this interesting but difficult group.—Alan Stone, Div. of Insect Identification, B.E.P.Q., U.S. Dept. Agriculture, Washington 25, D.C.

OBSERVATIONS OF THE PERSISTENCE OF PLASMODIUM INFECTIONS IN ANOPHELES MOSQUITOES IN AN AREA OF LOW OBSERVED HUMAN MALARIA PARASITEMIA IN SOUTH CAROLINA. By Wm. C. Frohne, Albert A. Weathersbee, Giles M. Williams, and John W. Hart, Journ. Nat. Mal. Soc. 9(1):10–24. 1950. 1. Data are presented on malaria incidence as determined by monthly blood films for a period of 51 months in a Negro population of about 600. The parasitemia rate dropped from 38.2 per cent in October 1944 to 0.0 per cent in 1946, and has remained low during 1947 and 1948.

2. The results of dissection of 33,593 *A. quadrimaculatus* in 1945 and 1946 and of 10,589 in 1947 and 1948 show a generally parallel drop in the annual sporozoite (gland-positive) rates. Rates of the 4 successive years are: 0.17, 0.07, 0.09, and 0.04 per cent, respectively.

3. Similarly, the sporozoite rates of 5,138 *A. crucians* dissected in 1947 and of 8,384 in 1948 were 0.14 and 0.06 per cent, respectively.

4. Densities for both species of *Anopheles* were determined from weekly averages of dissection station counts. There were low densities in 1947, but *A. crucians* densities were not so greatly depressed as those of *A. quadrimaculatus*.

5. During 1947 and 1948 when human parasitemia rates were insignificant, 4 individual stations yielded 5 sporozoite-positive *quadrimaculatus*, and 9 stations furnished 12 infected *crucians*. In 4 instances gland-positive mosquitoes of both species came from the same stations. Positive *crucians* were found in all *quadrimaculatus-positive* stations except one vacant house from which less than 200 *crucians* were dissected in 2 years.

6. A formerly malarious neighborhood of 4 dissection stations produced the 2 infective *quadrimaculatus* of 1947 and 3 of the 7 infective

crucians. In 1948 the same small neighborhood without any demonstrable human parasitemia during all 12 months, nevertheless furnished 50 per cent of the infective *Anopheles* found, though only 12.6 per cent of the mosquitoes dissected came from there.

7. In the study area the residual spraying of dwellings with DDT was carried on from 1945 through 1948. During that period human malaria parasitemia decreased in the ratio of 318 to 1. In spite of this remarkable reduction in parasitemia, and doubt regarding any recent new infections, the conclusion is reached that a minor amount of malaria transmission may be occurring in the study area for the following reasons: (1) Sporozoite-positive anophelines were present at specific locations in association with human parasitemia. Further investigations to determine the nature of these sporozoite infections is necessary before the definite conclusion can be drawn that they are not of human origin. (2) *P. falciparum* infections in the human host are atypical. These usually are asymptomatic, persist for long periods, and are highly infective to *Anopheles* even when gametocyte rates are extremely low. Thus, it is possible that a higher percentage of the human population is infective to *Anopheles* than is indicated by the monthly human parasitemia rates.—Authors' summary and conclusions.

A FIELD STUDY ON "GAMMEXANE" AND MALARIA CONTROL IN THE BELGIAN CONGO. II. THE EFFECT OF THE SPRAYING OF HOUSES WITH "GAMMEXANE" ON THE MOSQUITO POPULATION AND ON THE MALARIA INCIDENCE IN CHILDREN. By G. Davidson. Ann. Trop. Med. and Parasitol. 44(1): 1–26. 1950. "Gammexane" deposits applied in commercial water dispersible formulations at rate of 10 mg. gamma isomer per square foot retained toxicity against *Anopheles moucheti* for three months. Dwellings sprayed were mudwalled, often whitewashed, with roofs of corrugated metal, cement tiles or leaves.

The density of *Anopheles gambiae*, though low in the area was thought to have remained low during flood conditions due to spraying.

Untreated houses within a treated village harbored large numbers of *A. moucheti* after most of houses had been treated, emphasizing importance of treating every house. Complete spraying of isolated villages failed to effect local eradication.

Stomach and ovary dissections showed that over-all age level of *A. moucheti* was reduced, with a corresponding reduction in biting rate and egg laying. On basis of salivary gland examinations, malaria transmission was judged to have ceased.

"Gammexane" treatment described was ineffective against *Taeniorhynchus (Mansonioides) africanus*.

Blood film examinations of children 9 months and one year after beginning of spraying did not reduce rate of parasitemia but intensity of infections decreased. Parasite rates and intensities increased among children in untreated villages during a corresponding one year period. Infant infection rates were similar in treated and untreated villages. Population movements tend to nullify effect of treatment on malaria incidence in particular parts of the area.—Robert H. McCauley, Jr., U. S. Public Health Service, Manning, S. C.

BIOLOGICAL AND CROSSBREEDING STUDIES ON *Aedes hebrideus* AND *Aedes pernotatus*. By Wm. J. Perry. Ann. Ent. Soc. Amer. 43(1):123–136. 1950. Almost all culicidologists who have been concerned with control or taxonomic aspects of mosquitoes in the Pacific Basin have an appreciation of certain group complexes which have until recently been confused. During World War II certain Culicid species known to be efficient disease vectors were erroneously reported from localities where the distribution of the species does not extend. Medically, species differentiation of some of the "groups" is extremely important. *Aedes pseudoscutellaris* collected in nature in Samoa (Byrd and St. Amant 1945) exhibited a 9.9 percent larvae *W. bancrofti* infectivity rate. *Aedes hebrideus*, which had been previously determined as *A. pseudoscutellaris* epidemiologically is not responsible for the transmission of this disease.

Biological and crossbreeding studies made on two closely related forms of the *scutellaris* group from the New Hebrides Islands, *Aedes hebrideus* and *Aedes pernotatus*, led the author to the conclusion that both are true morphological species. Ability to hybridize only with extreme difficulty under laboratory conditions, and morphological differences in the larval, pupal and adult stages, including distinct hypopygial features, support this belief. No apparent intergrades have been found in nature even though on Esperitu Santo, in the New Hebrides, both occur together.

No ova were produced in crossbreeding experiments between female *A. pernotatus* and male *A. hebrideus*. Fertile ova were produced with the reverse sex combination. Intergrading characters were produced in larvae of the first generation with the progeny exhibiting features tending toward the maternal type, *A. hebrideus*. Larvae showed greatest variation in the sclerotic plate of the fourth instar. Second generation progeny showed greater alteration of structure of the sclerotic plate. Four males with a terminal pattern similar to *A. pernotatus* and a single imperfectly developed female was obtained in this group.

The medical importance of the two species in these Islands is not significant.

Biological accounts are given for the two species which include clear tables with reference to aquatic development. Six excellent plates adequately illustrate the critical larval, pupal, adult, and male terminalia of the two species and also contrast selected variations in larvae and adults of the first and second generation progeny.—Theodore Aarons, Alameda County Mosquito Abatement District, Oakland, California.

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